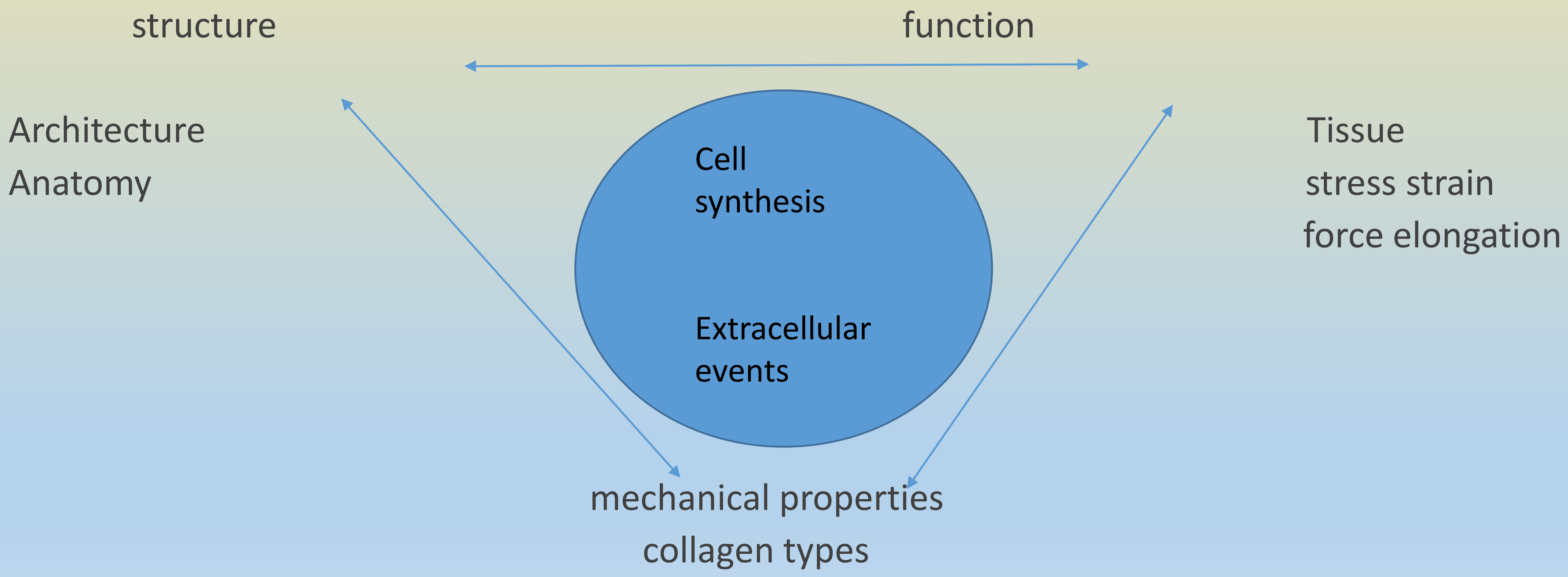
JOINT STRUCTURE AND FUNCTION

tissue structure – function



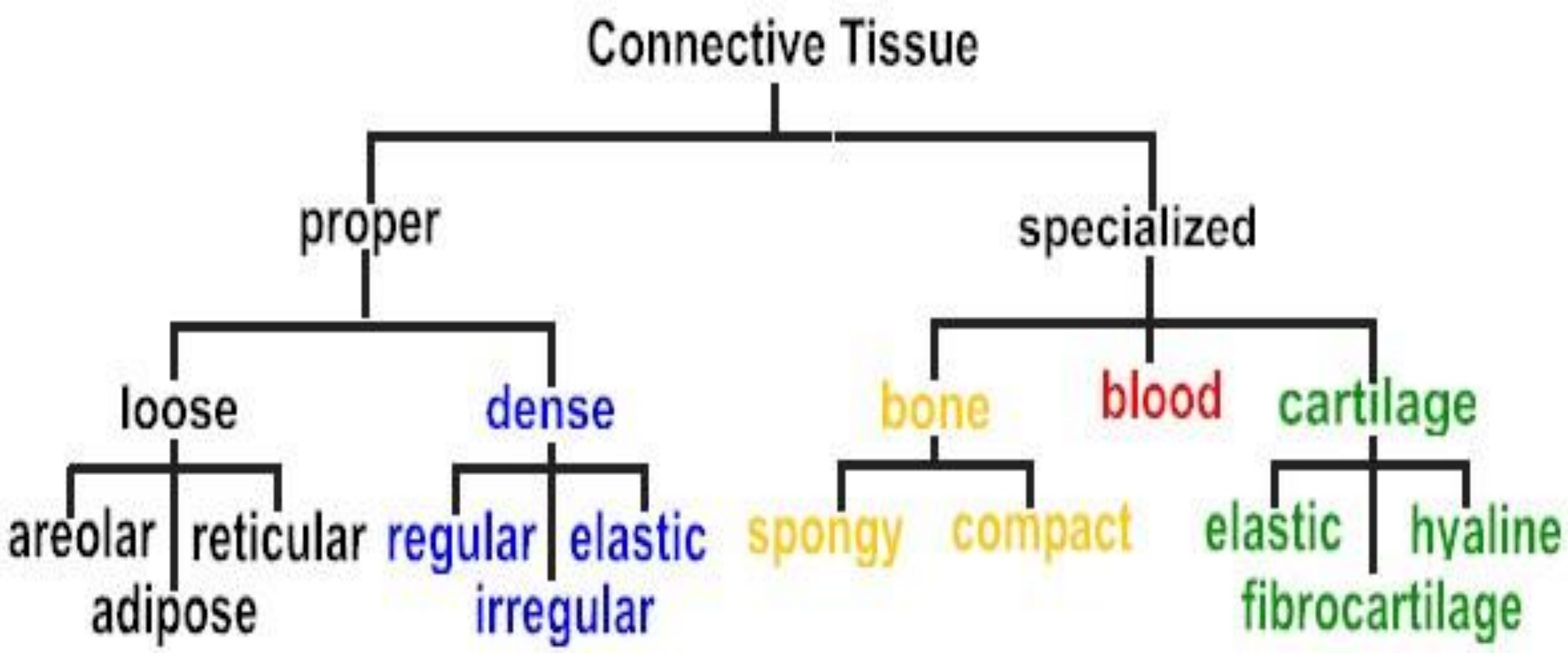
- Form determines the overall structure of connective tissue, but characteristics of the tissues are affected by functional use.
- Size of the tissue and its composition will determine the types of loads the tissue can bear.
- A joint /articulation connects two or more components of a structure
- Design of a joint depends on function of joint and nature of components.
- Joints that provide stability have different design than joints that provide mobility

- The joints that serve single function are less complex than joints that serve multiple functions
- The design of the joints is determined by its function and the nature of its components

❑ MATERIALS IN HUMAN JOINT

❖ *Structure of connective tissue*

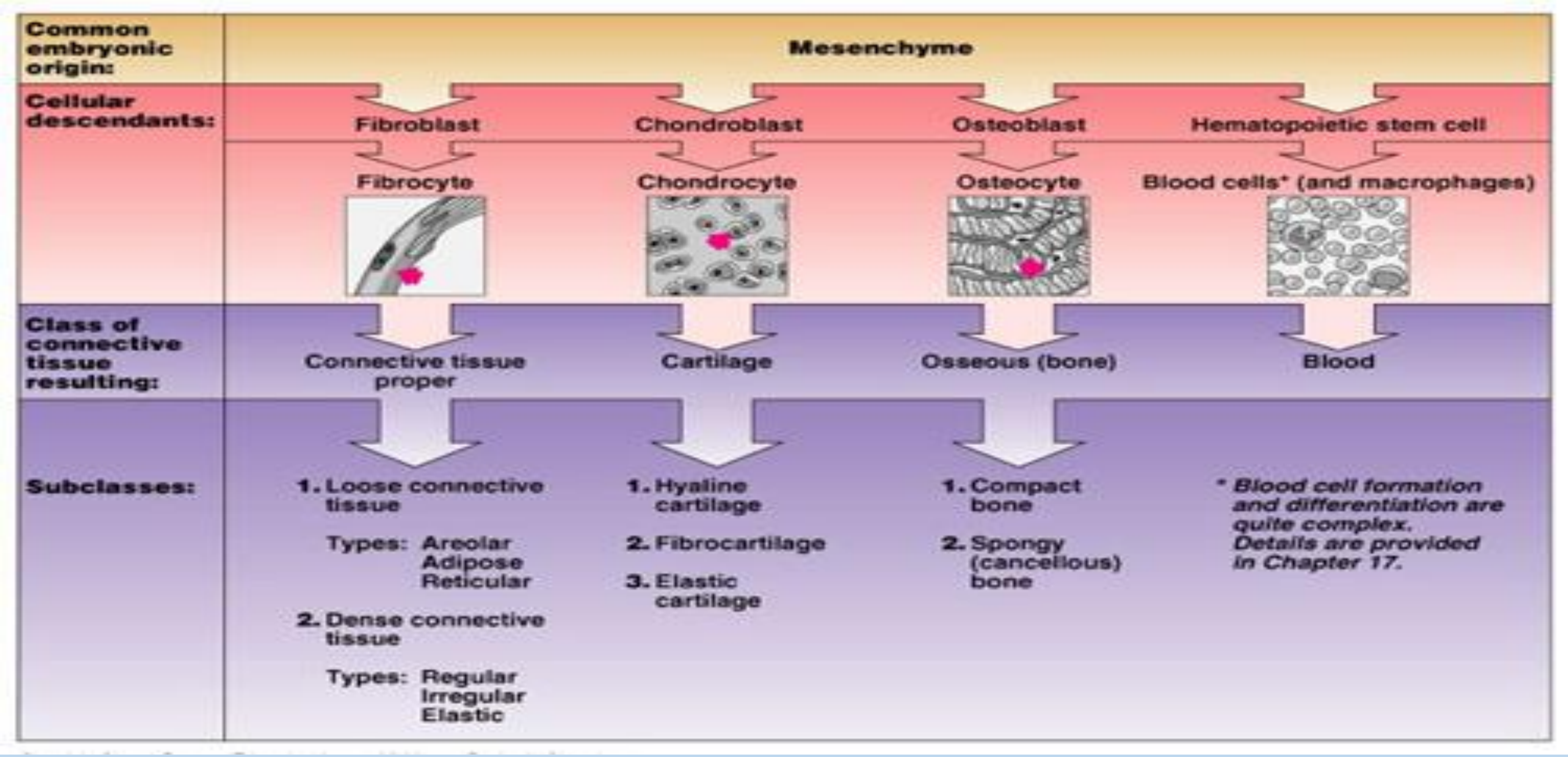
- They are in form of bones, bursae, capsules, cartilage, disks, fat pads, menisci, plates, tendons.


Connective Tissue
proper
specialized
loose
dense
bone
blood
cartilage
areolar
reticular
adipose
regular
elastic
irregular
spongy
compact
elastic
hyaline
fibrocartilage

- Connective tissue has a wide dispersion of cells (cellular component) and a large extracellular matrix.
- Extracellular matrix has both interfibrillar(ground substance) and fibrillar(fibrous) component.

- ***Cells***

- Cells of the connective tissue derive from mesenchymal precussor cells.
- The fibroblast is basic cell of most connective tissue, it procudes extracellular matrix.


Common embryonic origin:
Mesenchyme
Cellular descendants:
Fibroblast
Chondroblast
Osteoblast
Hematopoietic stem cell
Fibrocyte
Chondrocyte
Osteocyte
Blood cells* (and macrophages)
Class of connective tissue resulting:
Connective tissue proper
Cartilage
Osseous (bone)
Blood
Subclasses:
1. Loose connective tissue
Types: Areolar
Adipose
Reticular
2. Dense connective tissue
Types: Regular
Irregular
Elastic
1. Hyaline cartilage
2. Fibrocartilage
3. Elastic cartilage
1. Compact bone
2. Spongy (cancellous) bone
* Blood cell formation and differentiation are quite complex. Details are provided in Chapter 17.

- Fibroblasts specialize to become chondroblasts(Cartilage), tenoblasts(tendon) or osteoblasts(bone). These cells are called fibrocytes, chondrocytes and osteocytes when they mature.
- Connective tissue structure can be modified by changes in loading conditions.

■ *Extracellular matrix*

- It comprises mainly proteins and water and is divided into fibrillary and interfibrillar component.

- Fibrillar component
- It contains collagen and elastin
- Collagen is found in all multicellular organisms.
- It is the most abundant protein in human body(25%- 30%)

TABLE 2.1, 2.2,2.3,2.4,2.5

- The building block of collagen is a triple helix of three polypeptide chains called tropocollagen molecule.
- Peptide chains are synthesized in rough endoplasmic reticulum inside the fibroblasts and then move through the cell towards the cell membrane.

- The tropocollagen molecules aggregate to form microfibrils as they leave the cell, outside the cell they combine to form fibrils of varying size.
- Intramolecular(between peptide chains within collagen molecule) and intermolecular crosslinks(between molecules of adjacent fibrils) stabilize and strengthen the enlarging fibrils.
- Fibrils collect to form fascicle
- Collagen fibers are arranged in different ways and vary in size and length.
- In relaxed tissues crimp is present which disappears when stretched.

- Elastin consists of single alpha like strands without triple helix.
- These strands are cross linked to each other to form rubber like elastic fibers.
- Elastin fibers branch freely and are found in all joint structures, skin, tracheobronchial tree, walls of arteries. Elastin forms smaller portion of fibrous component than collagen.

▶ Interfibrillar component

- Contains water and proteins, primarily glycoproteins and proteoglycans(PG/mucopolysaccharides)

- A glycoprotein is a protein with carbohydrate attached.
- Glycoproteins are found in all tissues, PGs are found in connective tissues mainly.
- The carbohydrate portion of PG consist of long chain of repeating disaccharide units called glycosaminoglycans(GAG)
- The main types of GAG are chondroitin 4 and chondroitin 6 sulphate, keratin sulphate, heparin, heparin sulphate, dermatan sulphate.
- Hyaluronan differs from other GAG because it is not sulphated and does not attach to the protein core.

- The PGs in extracellular matrix of the structure affect its hydration through the attached GAG. The GAG chain attract water into the interfibrillar matrix, creating a tensile stress on surrounding collagen network.
- The PG also form a reservoir for nutrients and growth factors that attach to PG molecules.
- The type of GAG in the PG also may change, depending on whether the tissue is subjected to compressive or tensile forces.
- Tissues subjected to compression (disc) have larger amount of chondroitin sulphate and keratin sulphate.

- Tissues subjected to tension(tendon) contain more dermatan sulphate.
- Glycoproteins such as fibronectin, laminin, chondronectin, osteonectin, tenascin,chondromodulin and entactin play a role in fastening components of extracellular matrix together.

CONCEPT 2.2,2.3

- specific connective tissue structures

- ***Ligaments***

- Ligaments connect one bone to another, usually at or near to the joint
- Ligaments may blend with joint capsules and appear as thickenings in the capsule.
- They are heterogenous structures containing small amount of cells and large extracellular matrix.
- The fibrillar component of extracellular matrix in most ligaments is composed of mainly type 1 collagen and less elastin(ligamentum flavum)

- The type 1 collagen fibrils in ligaments are densely packed, with fiber bundles arranged in line with applied tensile forces.
- The arrangement of the collagen fibers and collagen/elastin ratio in various ligaments determines the ability of the structure to provide stability and allow mobility for a joint.
- Ligaments are subjected to varying tensile forces depending on joint angle, so the collagen fibers in ligaments run in many directions ,enabling the ligament to resist forces in more than one direction.
- Tensile forces on tendons are applied in one direction, so collagen fibers are straight and parallel.

- The appearance and composition of ligaments and tendons change near their enthesis(attachment to the bone)
- Tendons and ligaments insert directly to the bone via fibrocartilage or indirectly via fibrous attachments.
- In fibrous attachment the collagen fibers blend into the periosteum of the bone which is in turn attached to the underlying cortical bone via sharpey’s fibers.
- Ligaments are named according to their

  location and shape - anterior longitudinal ligament bony attachment- coracohumeral ligament

shape- deltoid ligament

- *Tendons*

- Connect muscle to bone and transmit forces developed by the muscles to their bony attachments.
- Prominent tendons are named for the muscle to which they are attached –biceps tendon for biceps brachii.
- Tendons and ligaments have a similar composition and basic structure, though the proportions and organization of the components of extracellular matrix differ.

- Tendons contain mostly type 1 collagen,which is an adaptation to larger tensile forces.
- The interfibrillar component of extracellular matrix in tendons contain water, PG that contain mainly dermatan sulfate and other glycoproteins.
- The diameter of the fiber increases with age and with increased tensile loading.
- Groups of fibers enclosed by loose connective tissue sheath is called endotendon.

- The endotendon also encloses type 3 collagen fibrils,erves,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.

FIG 2.8,2.9

- A tidemark appears between calcified and uncalcified parts of enthesis, representing the boundary between hard and soft tissues.
- The fibrous attachment can be divided into 2 categories: periosteal and bony.
- The attachment of tendon to muscle is at myotendinous junction.

▪ ***Bursae***

- They are flat sacs of synovial membrane in which the inner sides of the sacs are separated by fluid film.

- Bursae are found where moving structures are in tight approximation (tendon and bone, bone and skin, muscle and bone, ligament and bone.
- Subcutaneous bursae are located between skin and bone.
- Subtendinous bursae lie between tendon and bone.
- Submuscular bursae lie between muscle and bone.

▪ *Cartilage*

- It is divided into the following types:

Fibrocartilage (white)

elastic cartilage (yellow)

hyaline (articular)

- Cartilage contains mainly type 2 collagen and large amounts of aggregating PGs
- Fibrocartilage forms the bonding cement in joints where little motion occurs such as intervertebral discs .
- Yellow elastic cartilage is found in ears and epiglottis and has more elastin .

- Hyaline cartilage forms a thin covering at the ends of the bones in synovial joints. It provides a smooth, resilient, low friction surface that distributes weight. Once injured the articular cartilage has limited and imperfect mechanisms for repair.
- In the outermost layer (zone 1),radially oriented type 2 collagen fibers are arranged parallel to the surface. This reduces the friction between opposing joint surfaces and distributes forces over joint surfaces.
- In the second and third zones, there is an open network. The collagen network keeps the PGs and water contained giving the cartilage the ability to absorb forces.

- In the third layer (radiate stratum) ,perpendicular collagen fibers cross the interface between uncalcified and calcified cartilage .
- The calcified cartilage is sometimes called the fourth zone,and lies adjacent to subchondral bone and anchors the cartilage to the bone.
- The interface between the calcified and uncalcified cartilage is called tidemark. The tidemark is important because of its relation to growth ,aging ,injury and healing.

FIG 2.11.

- The cartilage has no cellular turnover,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.

- Equilibrium is reached between the swelling pressure and the load on the joint and deformation stops.
- Cartilage resistance to compressive forces depends on 2 features – a large volume of PGs and intact collagen network.
- In degeneration there is loss of superficial collagen fibers which allows more water to enter causing cartilage swelling. Without the collagen network, PGs escape the joint and cartilage narrows and loses its ability to resist compression.

CONCEPT 2.5

- During joint motion or when cartilage is compressed, the fluid moves through the joint space through the pores in outermost collagen layer. As the load is removed the fluid flows back into cartilage carrying the nutrients from the synovial fluid that supply the chondrocytes.
- Hyaline cartilage is devoid of blood vessels, thus the free flow of fluid is required for nourishment.
- Fluid flow is affected by the magnitude and duration of applied force.
- If the force is increased and sustained for a long period ,equilibrium between swelling pressure in the cartilage and external load reduces the fluid flow.

- The absence of compressive forces on the cartilage surface reduces the movement of fluid, which remains immobilized in the extracellular matrix.
- Hyaline cartilage can thus undergo degeneration
- Damage to the superficial collagen layer, through excess firictional forces or trauma removes the meshwork that resists the swelling pressure in PGs.
- Initially the articular cartilage swells and becomes thicker as the PGs attract more water without the opposing force of superficial collagen network.
- Gradually fluid movement slows, reducing cell nutrition.
- PGs begin to escape into synovial fluid, eroding and thinning the cartilage.
- This sequence occurs during osteoarthritis.

- ***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 called cancellous/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.

- 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.

- 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

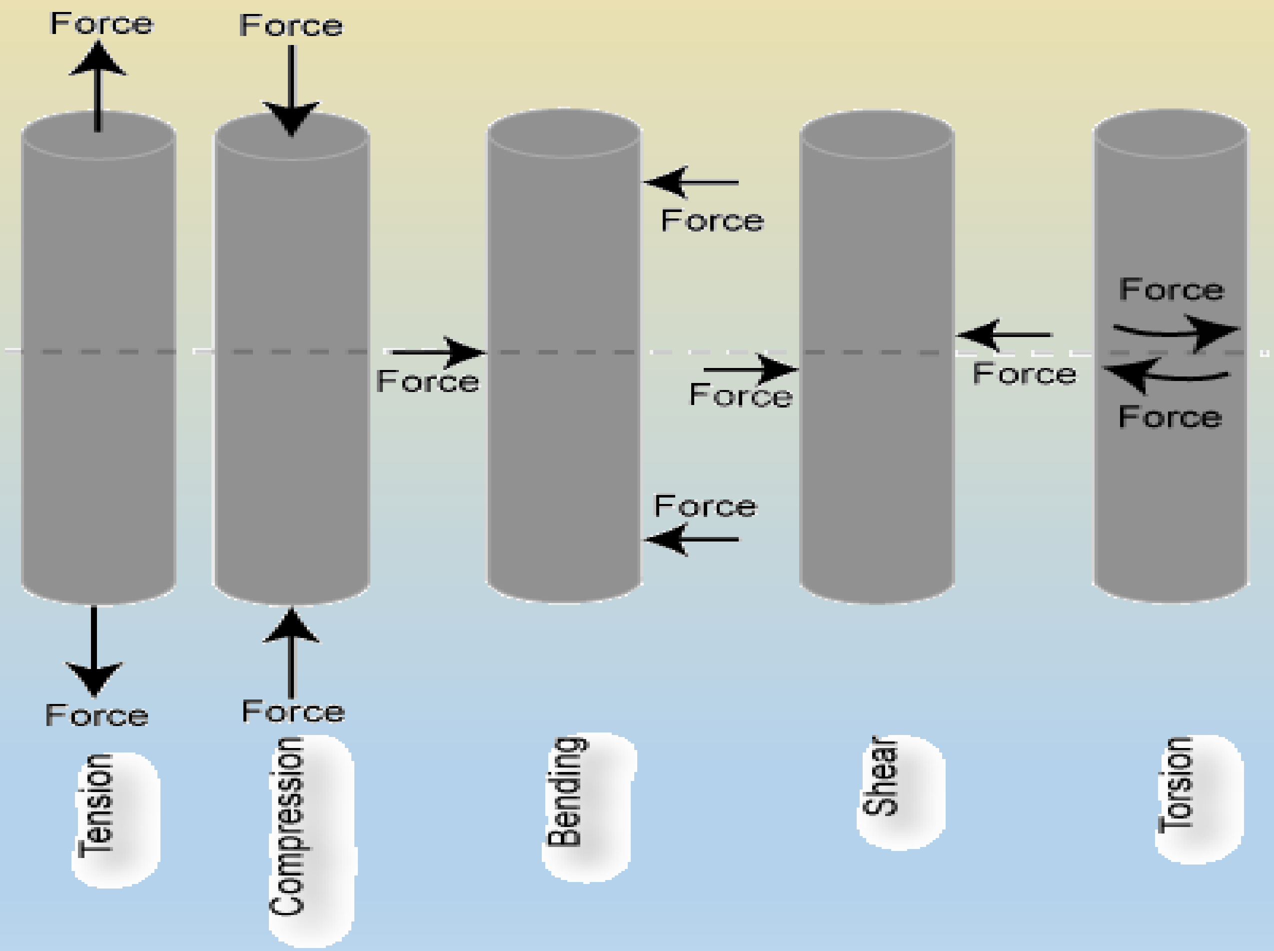
. Type of load

. Point at which the load is applied

. Direction and magnitude of the load

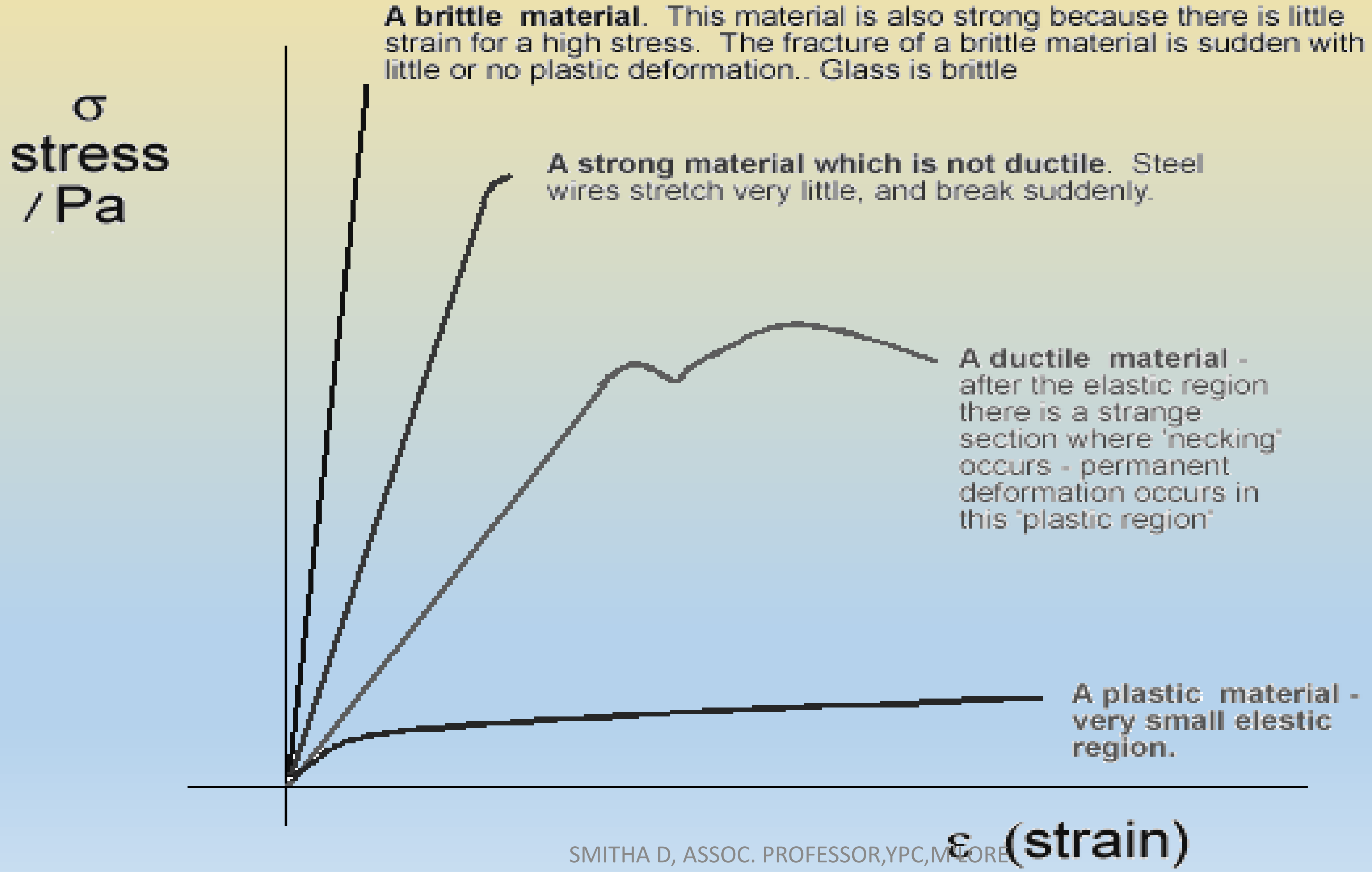
. Rate and duration of load.

- 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
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.

- The stress strain curve can be used to compare the strength properties of one material with that of another material or to compare the same tissue under different conditions.
- The stress strain curve has same points as load deformation curve but the shape of the curve and the amount of stress and strain will vary with composition of the material.
- The curve will be flatter in elastic materials and steep in stiff materials.


σ
stress
/ Pa
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
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 (FIG 2.15)

- 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.

FIG 2.15

- 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

TIME	RATE

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

- 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

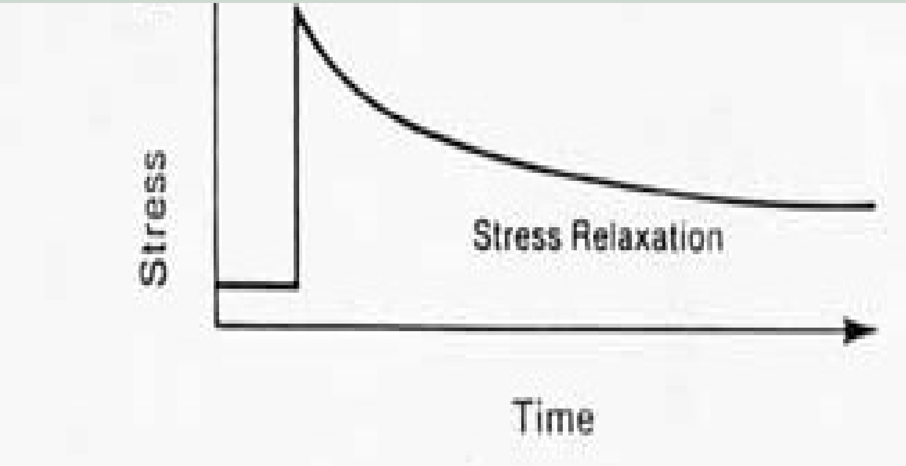
Tensile compressive

deformation

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

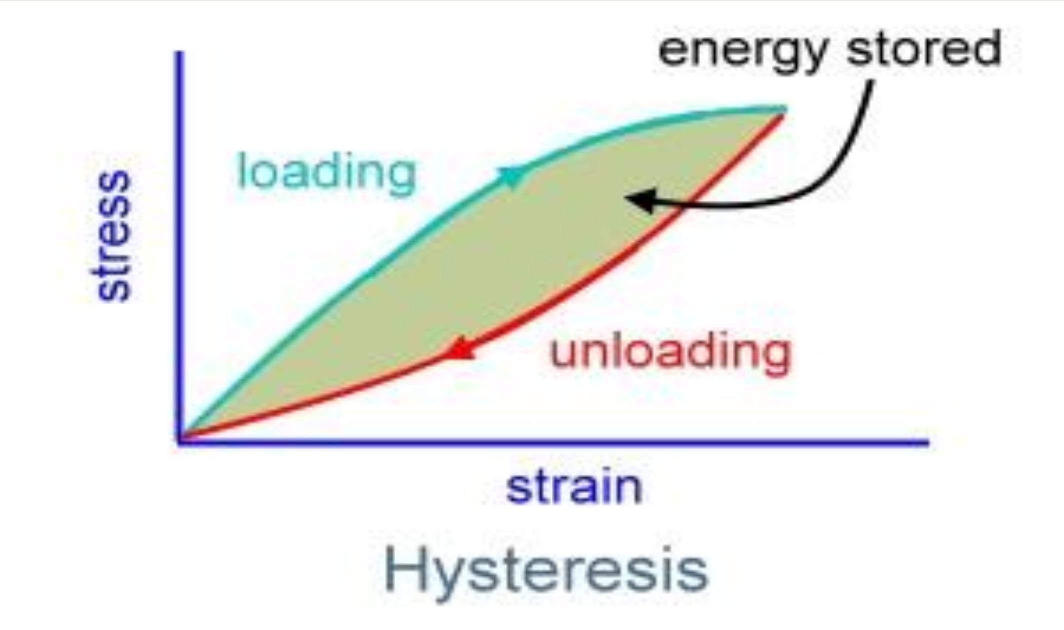
- Stress relaxation

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



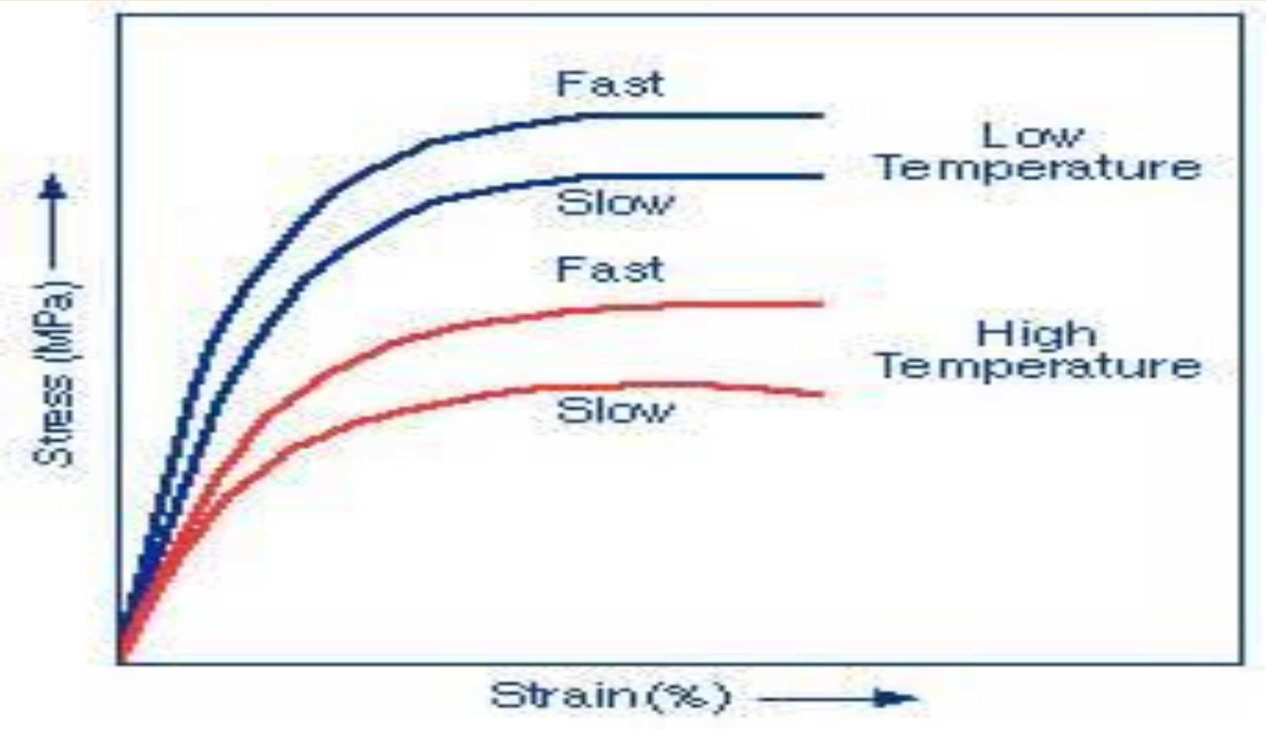
- Hysteresis

- Energy dissipated by elongation and heat released



- Strain rate sensitivity

-



- Stiff – rapid load
- Creep takes long time to appear in stiff materials.

❖ PROPERTIES OF SPECIFIC TISSUES

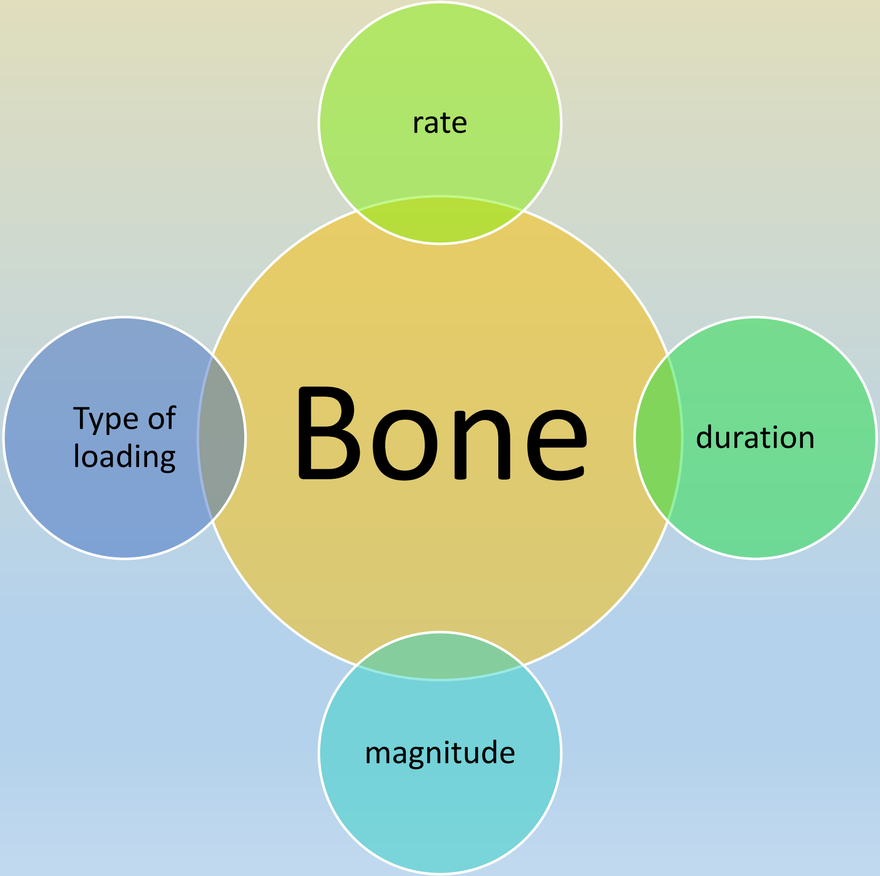
▪ BONE

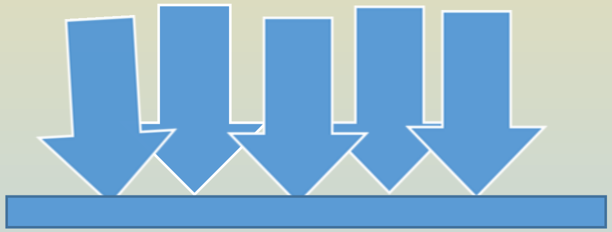
- Cortical bone(2%) is stiffer than cancellous bone(75%)

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

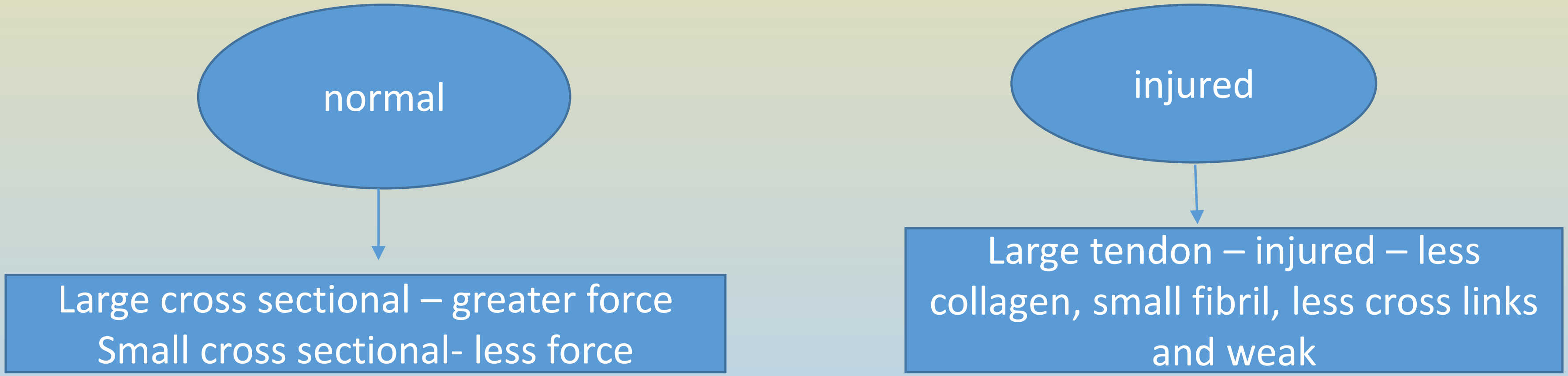
increase the loading

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

↓

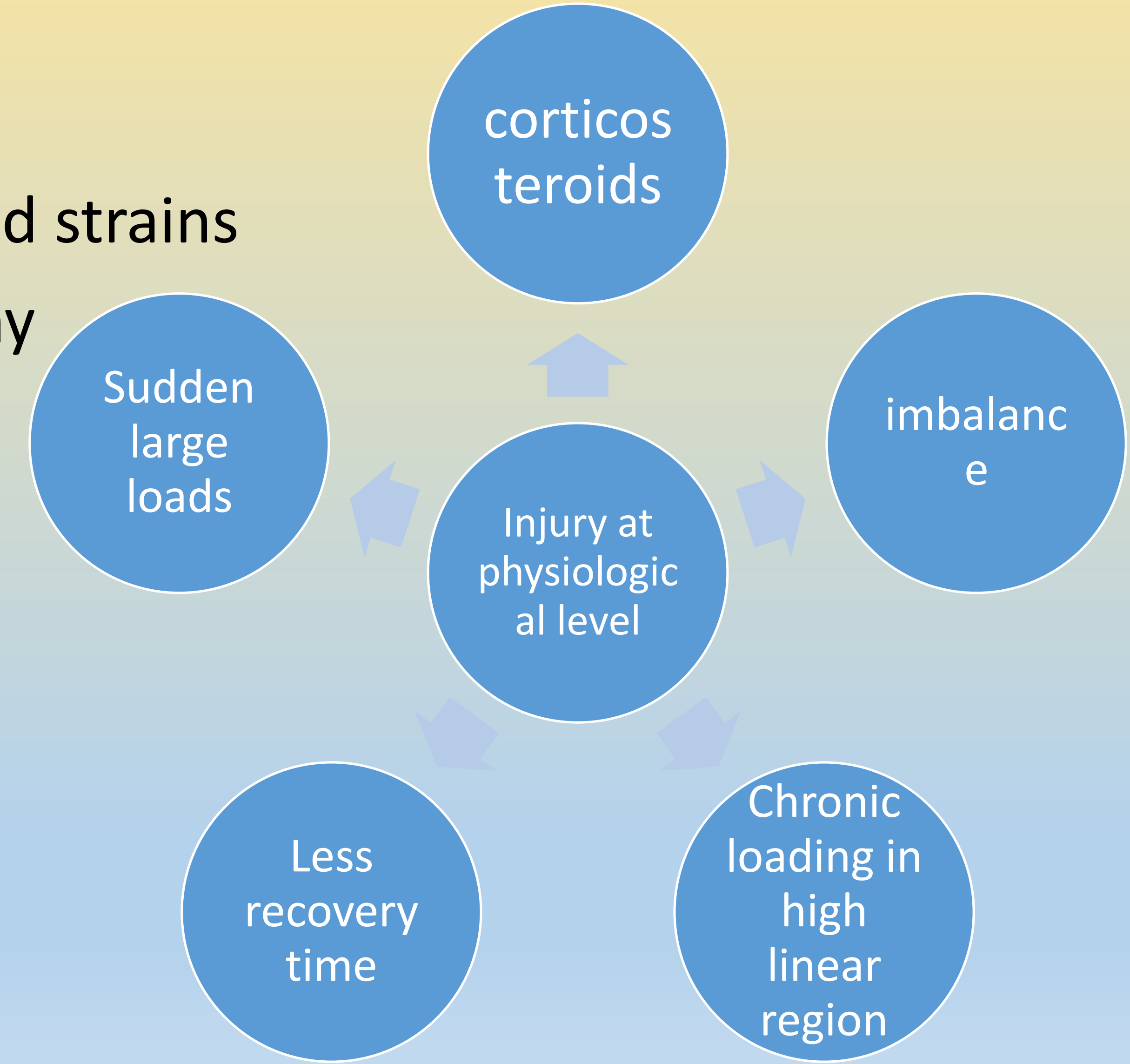
Straightened and weak fibers fail first

- Normal activities of everyday

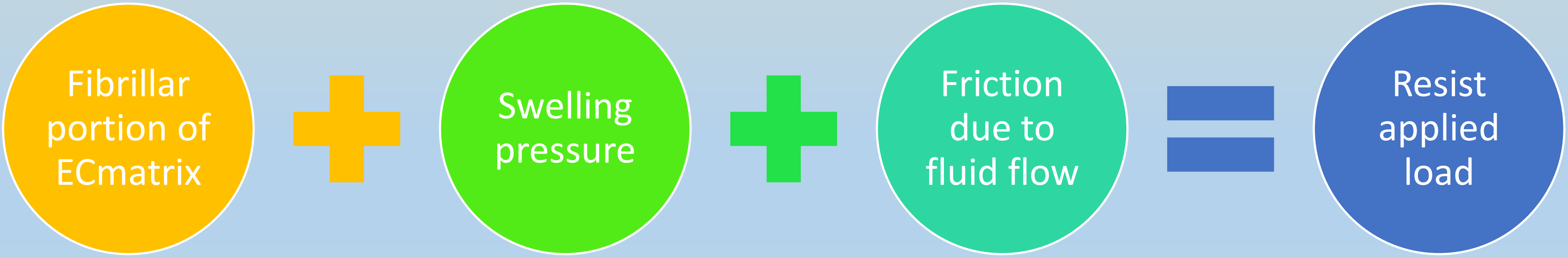


- Changes in composition
- Enthesis is common site for degenerative changes.

- 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



- 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

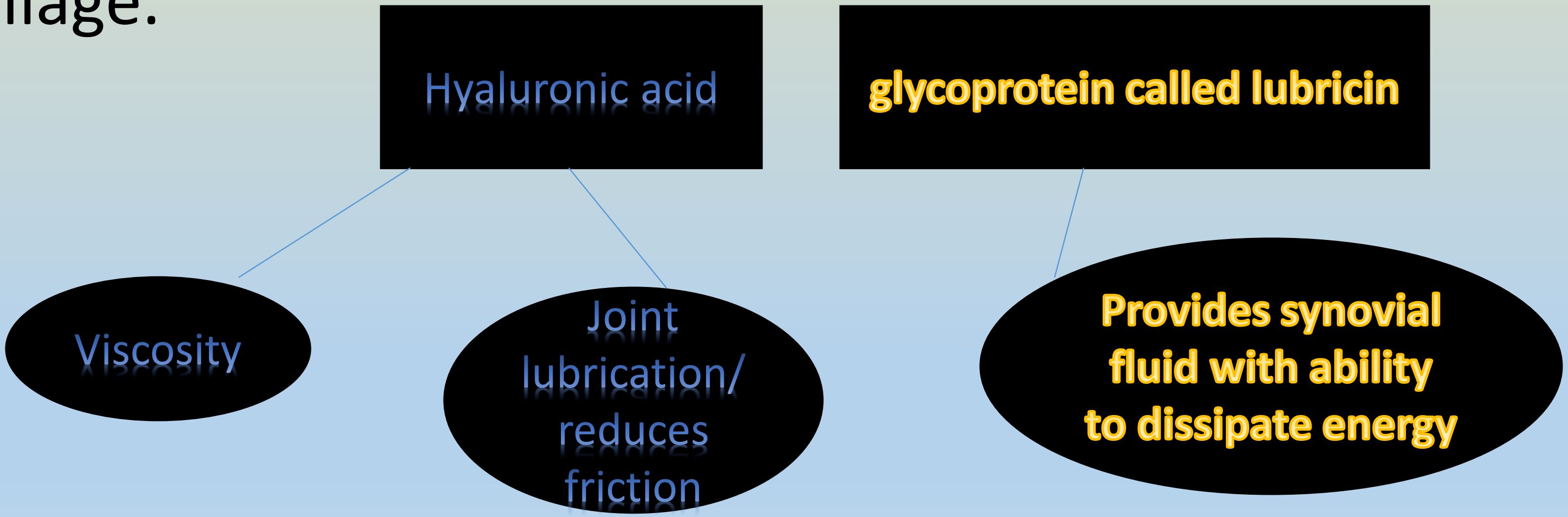
- When the compressed PGs and water push against the collagen fibers it creates hoop stresses.
- Toe region in cartilage–frictional drag
- Toe region in ligaments and tendons – straightening of collagen fibers.
- Shear stress in the cartilage develop between calcified layer and subchondral bone.

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.

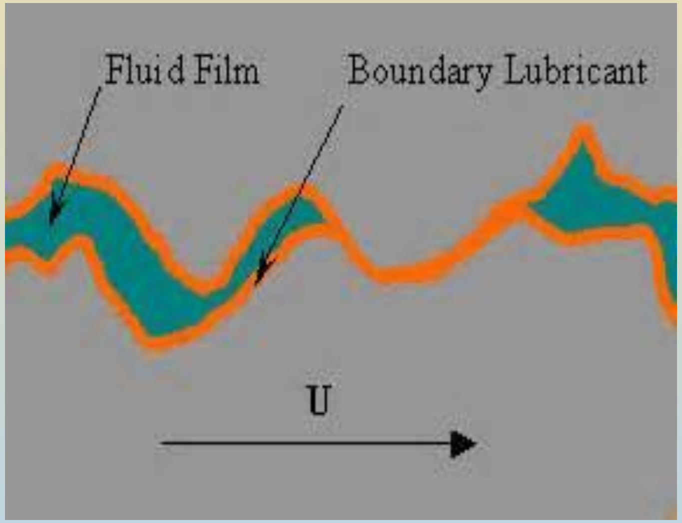


- All viscous substance resist shear load. High rate- less viscous(thixotropic)
- Rapid movement – reduces the viscosity –less resistance to motion.
- High temperature – less viscous and vice versa.

▪ JOINT LUBRICATION

- Models of lubrication

Boundary lubrication

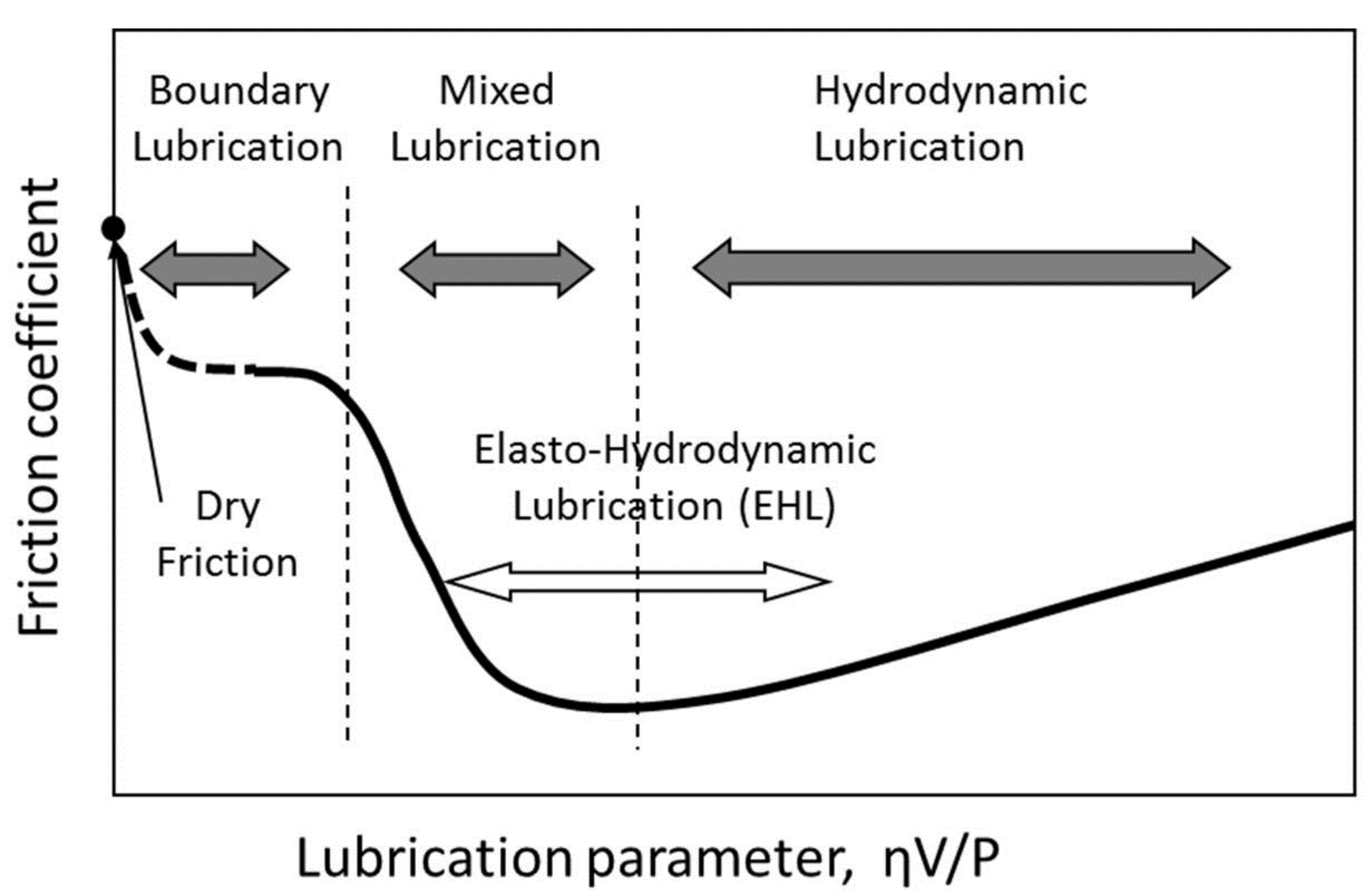


Fluid film lubrication

- Hydrostatic (weeping)
- boosted
- Squeeze film
- hydrodynamic
- Elastohydodynamic=hydrodynamic+squeeze film

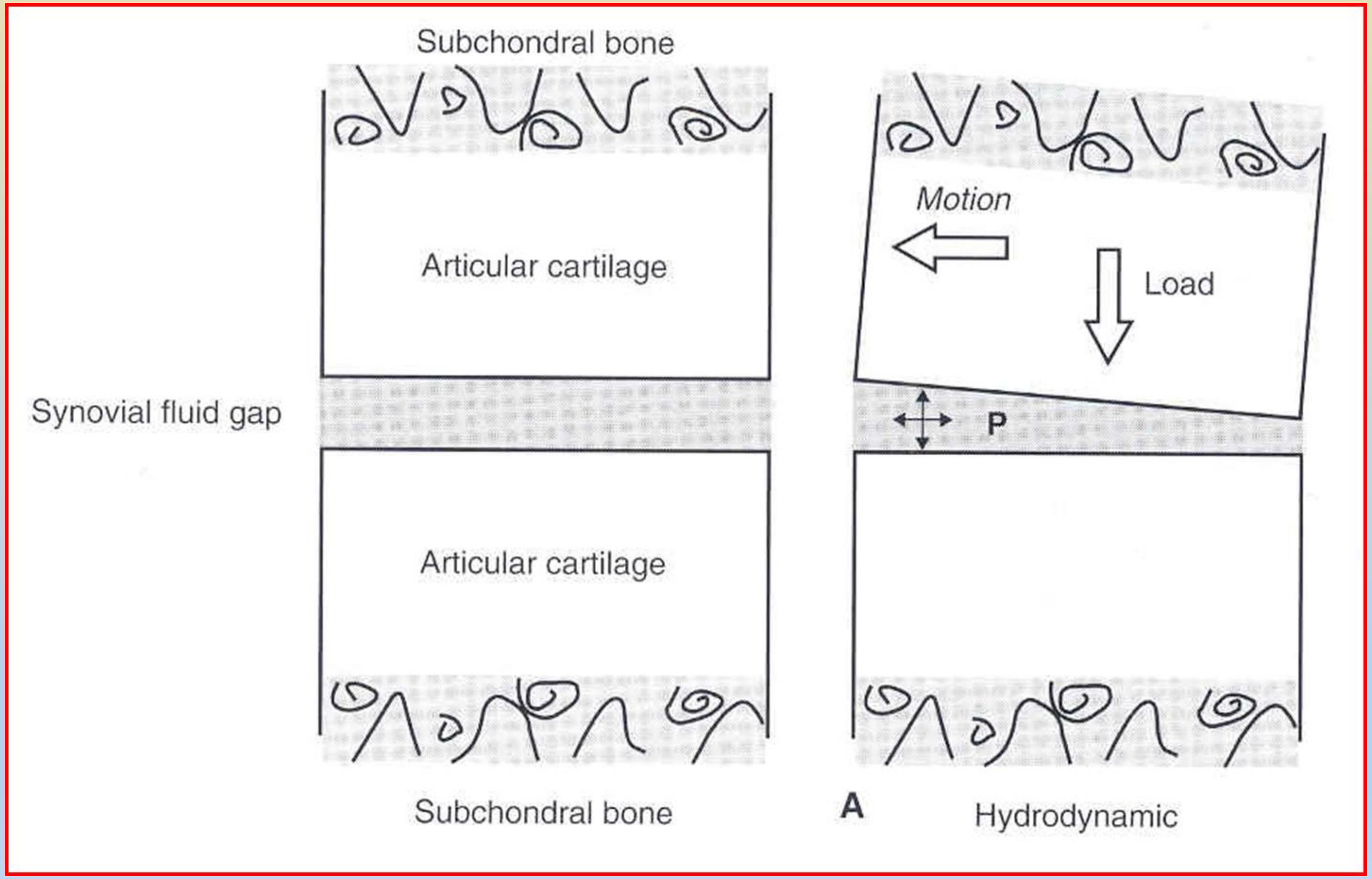
- Load bearing surface coated with molecules that separates opposing surfaces touching each other
- Effective at low loads.
- These contain lubricin

- Separates the joint surfaces

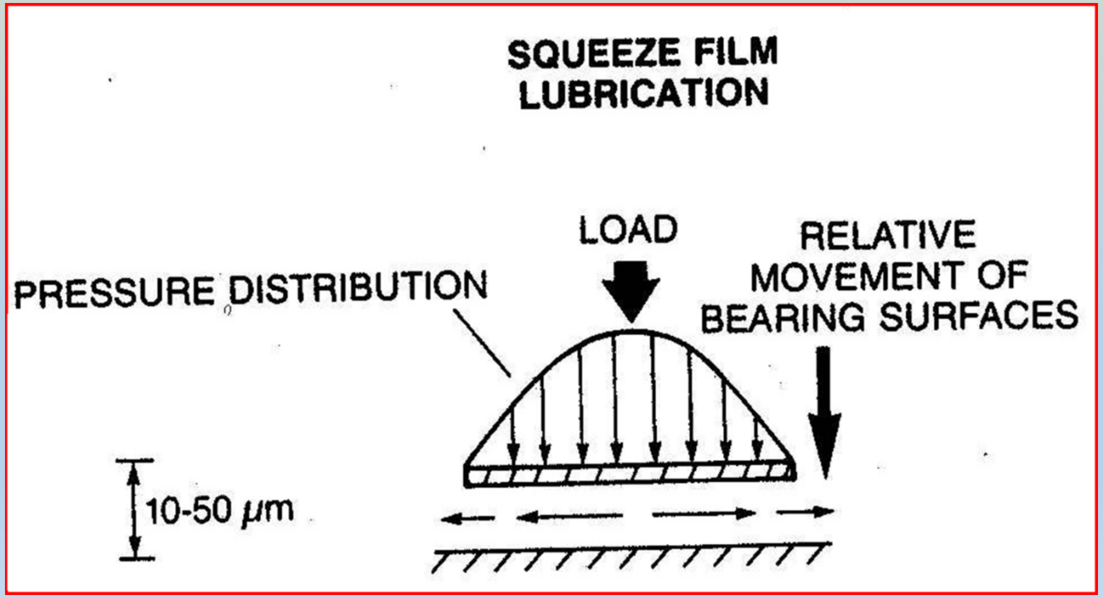


Boundary
Lubrication
Mixed
Lubrication
Hydrodynamic
Lubrication
Friction coefficient
Dry
Friction
Elasto-Hydrodynamic
Lubrication (EHL)
Lubrication parameter, ηV/P

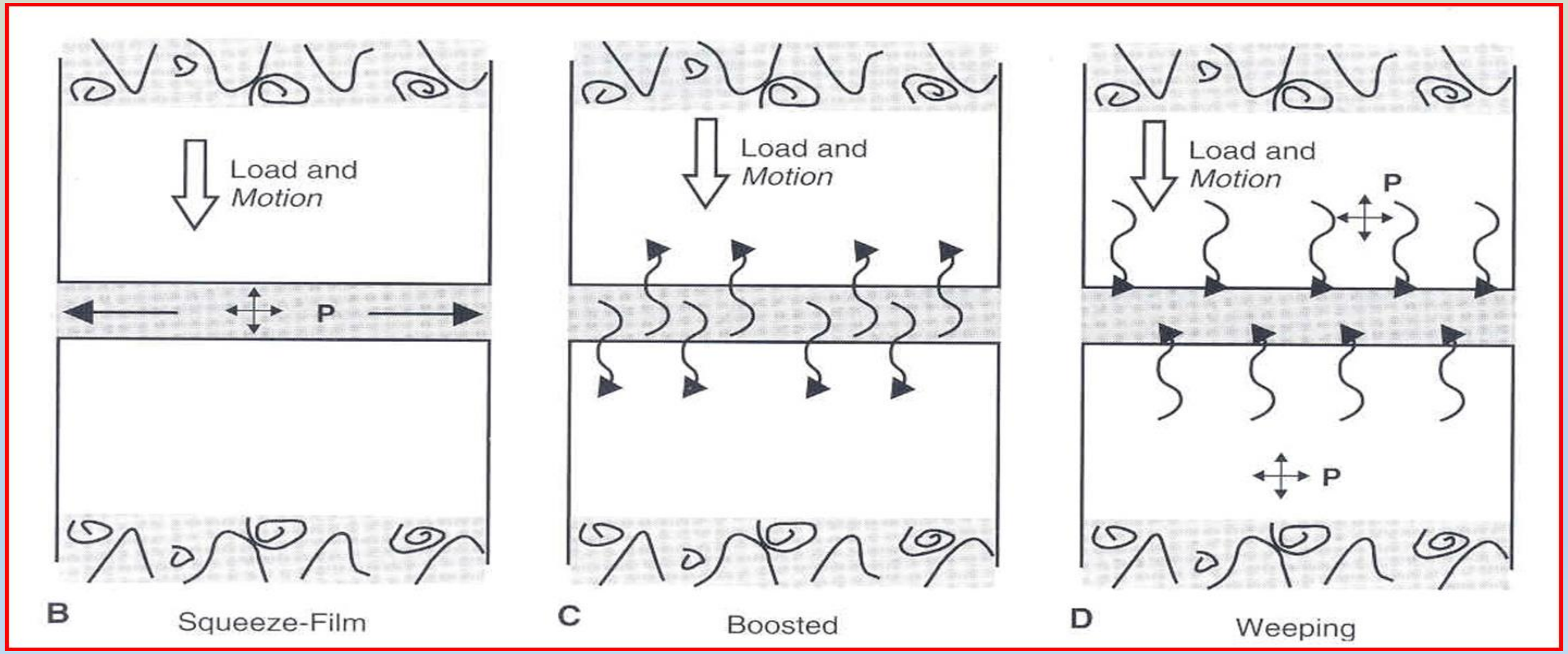
- In hydrostatic lubrication load bearing surfaces are held apart by film of lubricant maintained under pressure. This is by the contraction of the muscles/ compression.
- The fluid moves only into the joint and not the subchondral bone.
- Removal of the load
- In hydrodynamic lubrication a wedge of 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.



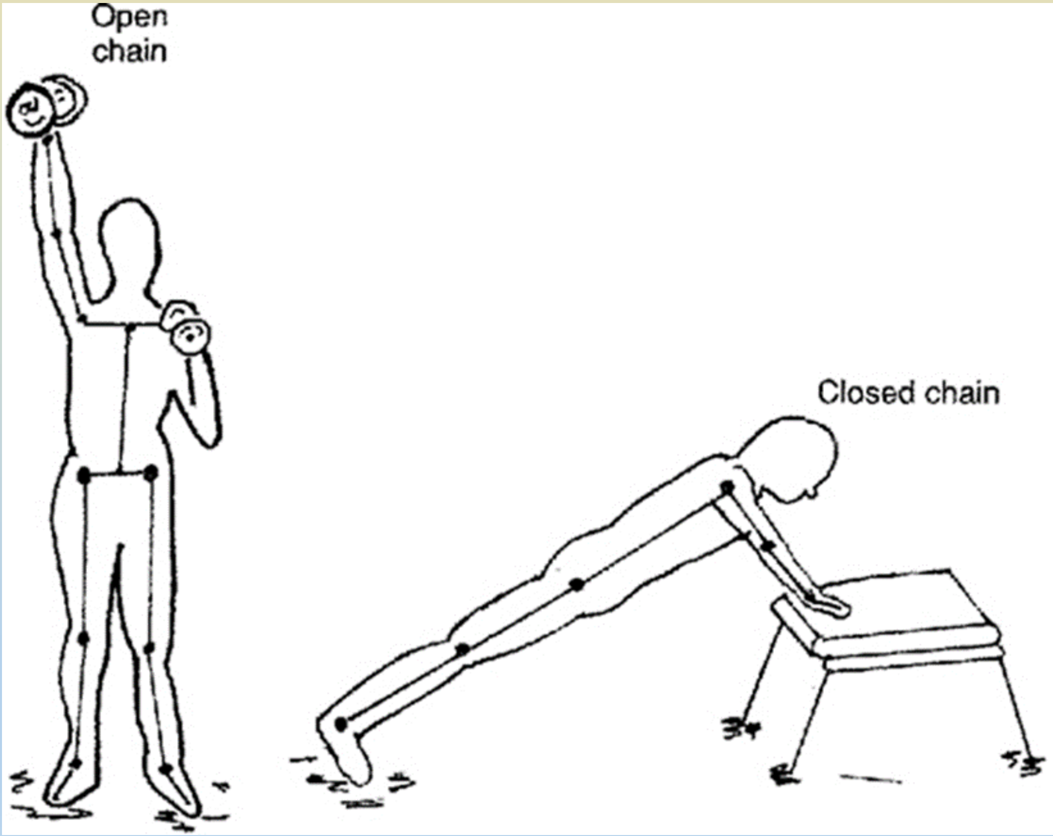
- In boosted lubrication the hyaluronate molecules are filtered out of the synovial fluid and are trapped in the area of elastic deformation on the articular surface.

CONCEPT 2.8

JOINT FUNCTION

❖ KINEMATIC CHAINS

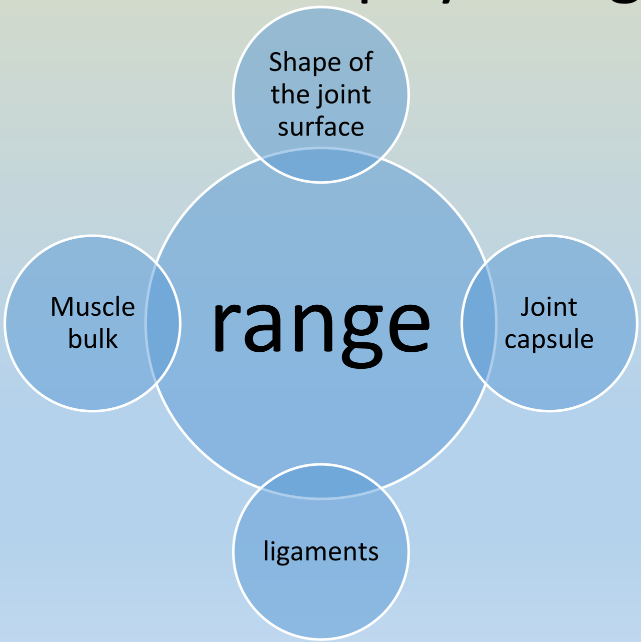
- In open kinematic chain, distal end of the chain is free to move and one joint can move independently of the other in the chain.
- In closed chain , both the proximal and distal ends of the chain are fixed .movement at one joint creates the movement in one or more joints of the chain.
- Closed chain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