

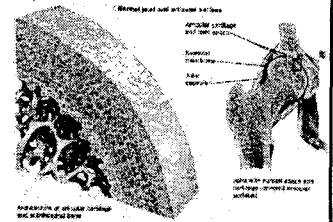
## Articular Cartilage

# Functional Anatomy & Biomechanics

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## Articular cartilage

- avascular
- aneural
- alymphatic



## Articular cartilage

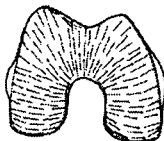
- highly organized & complex structure
- seemingly inert & homogenous
- can tolerate a tremendous amount of intensive & repetitive physical stress
- frequently lasts a lifetime
- manifests a striking inability to heal

## Articular cartilage

- immunoprivileged
- mechanical forces for biologic regulation
- supports 1-4Mpa(150-600lb / in<sup>2</sup>)
- average of 2million times each year

## Articular cartilage

- lower collagen content & more complex ultrastructure
- less tensile modulus & strength
- anisotropic material property "split-line" pattern varying collagen arrangement



## Function

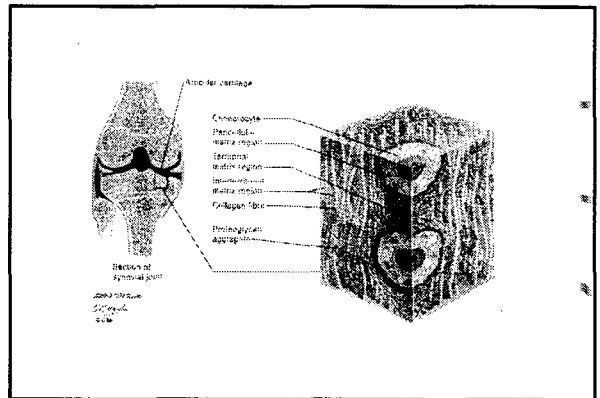
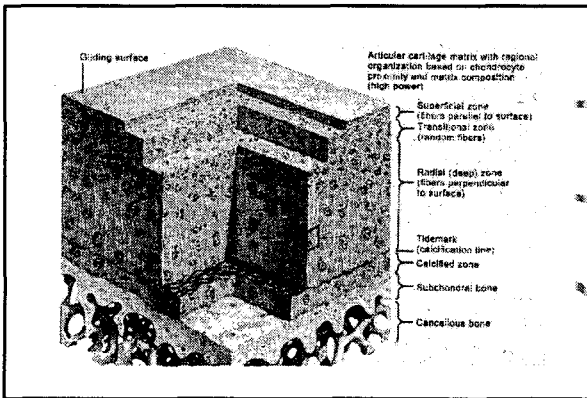
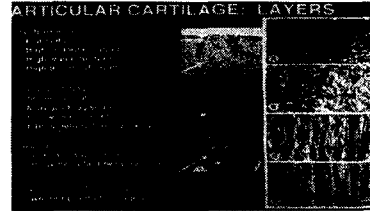
- load transmission & distribution
- shock absorption
- maintain contact stress at low level
- smooth, nearly frictionless

### Response to injury

- avascularity
- immobility of chondrocyte
- limited ability to proliferate & alter their synthetic patterns

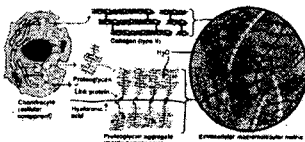
### Structure & composition

- varies three-dimensionally, distance from surface & relation to distance from the cells



### Composition

- chondrocytes
- functional extracellular matrix
  - collagens
  - proteoglycans
  - noncollagenous proteins
  - water: unique mechanical properties

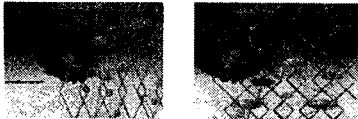


### Biochemical composition of adult articular cartilage

as % of total weight	
water	66-78%
solids	22-34%
as % of dry weight	
inorganic	
ash(HA)	5-6%
organic	
collagen(type II)	48-62%
proteoglycan	22-38%
noncollagenous matrix proteins	
	5-15%
minor collagens	< 5%
lipid	< 1%
hyaluronate	< 1%

### Water

- 60-80% of its wet weight
- move freely in & of cartilage when loaded, 70% movable
- bound proteoglycan-collagen gel
- exchangeable w/ synovial fluid



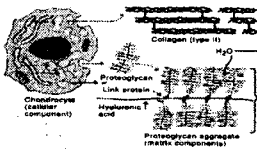
### Water

- many free mobile cations (Na, Ca)
- contribute to its material properties
  - joint lubrication
  - nutrition of chondrocytes
- maintain the resiliency
- control surface deformation & mechanical behavior



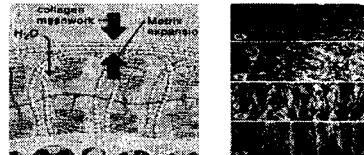
### Collagen

- 50% of dry wt.
- 90-95%: type II
  - IX, XI, V, VI
- synthesized in chondrocyte ribosome
- slow turnover - half life, > 3mo



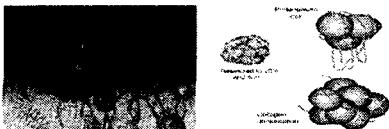
### Collagen

- structural framework
- counteracts the swelling pressure
- tangential orientation in gliding zone
- resists shear & surface wear



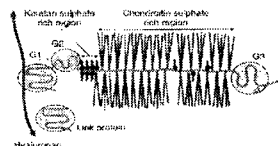
### Proteoglycans

- synthesized by chondrocyte
- test-tube brush shape
- found in only AC & NP
- compressed by collagen framework
- damage to collagen: expand PG & absorb more water



### Proteoglycans

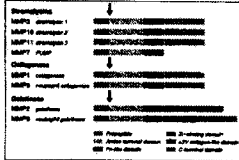
Composition  
: hyaluronate  
glycoprotein  
glycosaminoglycan (GAG) side chains





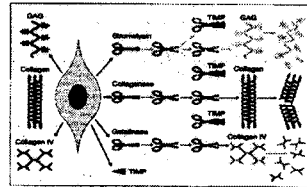
### Matrix metalloproteinases (MMPs)

- degradative enzymes - destroy aggrecan
- Collagenase
- Stromelysin
- Gelatinase

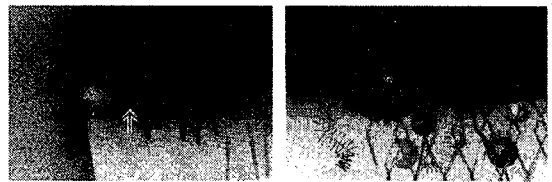
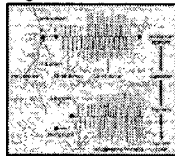
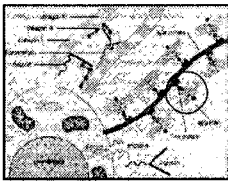


### Matrix metalloproteinases (MMPs)

- secreted by chondrocytes as a proenzyme under influence of IL-1 or TNF
- suppressed by TIMP (tissue inhibitor of MMPs)



### Enzymatic attack



### Proinflammatory cytokines

- IL-1
  - : in chondrocyte
  - stimulates collagenase & stromelysin
  - inhibits collagen & PG synthesis, & TGF- $\beta$
- TNF- $\alpha$  & TNF- $\beta$ 
  - : in synoviocyte
  - induces collagenase & PGE2

### Antiinflammatory cytokines

- IL-4
  - inhibits TNF- $\alpha$ , IL-1 & PGE2 synthesis
- IL-6
  - stimulates TIMPs

### Loss of matrix proteoglycans

- loss of compressive stiffness & elasticity:  
transmission of greater mechanical stress to chondrocytes
- increase in hydraulic permeability:  
greater loss of interstitial fluid  
affect cartilage self-lubrication

### Role of subchondral bone

- initiation & progression of cartilage damage
- stiffening of subchondral bone precedes & causes articular cartilage degeneration
  - progression of cartilage degeneration requires stiffening of subchondral bone

### Mechanical properties

#### Biphasic

: solid(porous) &  
fluid(imcompressible) phases

### Mechanical properties

#### Viscoelastic materials

- time dependent deformation  
& recover

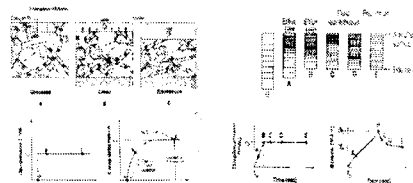
### Viscoelastic response

#### two mechanisms

- intrinsic viscoelastic p. of macromolecules
- frictional drag arising from flow of interstitial fluid (biphasic v.)

### Mechanical properties

- Biphasic creep response & stress-relaxation response

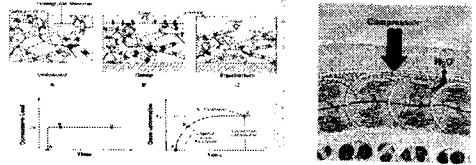


### Tensile properties

- highly nonhomogenous
- varying w/ depth
  - higher in superficial zone
- far less than tendon & ligament

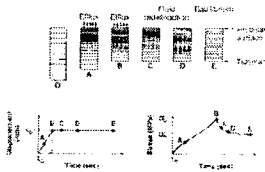
### Behavior in compression

- Biphasic creep response caused by exudation of interstitial fluid
- creep equilibrium: human 4-16 h  
rabbit 1h



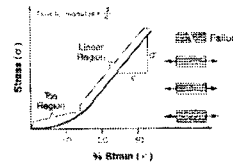
### Behavior in compression

- Biphasic stress-relaxation response
- result of fluid redistribution within matrix



### Behavior under tension

- stretched at extremely slow rate
- tensile stress-strain curve
- failure at strain greater than 30%
- strain increases w/ increasing depth



### Behavior in shear

- middle zone
- no pressure gradient or vol. change
- compression stiffens cartilage in shear
- resists high shear stress at uncalcified-calcified junction

*Thank you  
for your attention!*