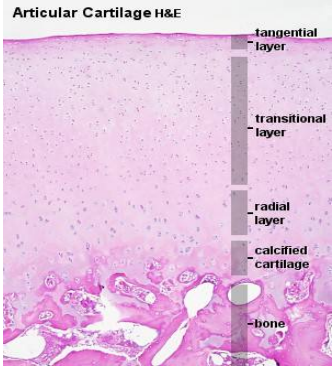
ME 482 Experimental Tissue Mechanics

Professor A. Wagoner Johnson

8/31/16 : Cartilage



Suggested reading: Nordin and Frenkel, Cartilage chapter plus others posted

CARTILAGE

General questions to be able to answer about cartilage…we will be more specific with articular cartilage (AC)

- What is cartilage??
- What are the different types of cartilage and how do they differ?
- How does their function generally relate to structure/composition?
- Where are they found?
- What is the important cell in this tissue?
- How is this tissue different from other tissues?
- Describe the hierarchical structure for AC (articular cartilage)
- What is the composition of AC and how does it vary with depth?
- How does the cell distribution vary with depth in AC?
- How do fibers vary with depth in AC?
- Why is there tensile anisotropy on the surface of AC?

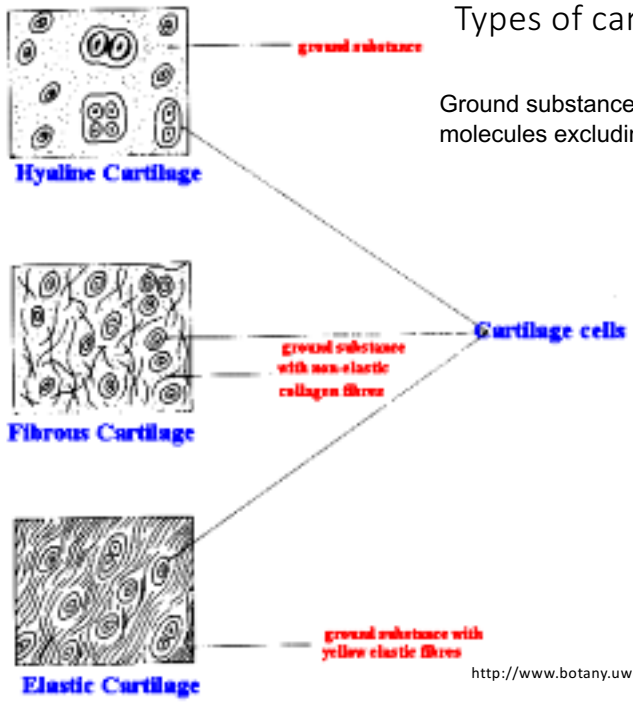
Points below are basically true for any cartilage

- Dense fibrous connective tissue
- Found in joints, rib cage, ear, nose, throat, between intervertebral discs, and more…
- Important for growth and development
  - Temporary skeleton as embryo - serves as a pattern for bone
- Forms growth plate – from which long bones grow until end of puberty
- Isolated tissue
  - No vessels, nerves, lymphatic system
  - Low cellular density
  - Water content very important
- Matrix manufactured by chondrocytes (cartilage cells)
  - Housed in lacunae – little pockets containing cells
  - No cell-to-to cell contact
  - Precise communication mechanisms unknown
- Nutrient and waste transport
  - By diffusion and fluid flow
  - Compressive loading moves waste and nutrients
  - Inactivity is not good for articular cartilage!

Some diseases of cartilage

- Osteoarthritis (not eligible for project)
  - Cartilage breaks down due to physical stress: wear and tear
  - Ends of bone thicken
  - Joint may loose normal shape
  - Two ends of the bones in the joint may begin to rub and cause pain
- Rheumatoid arthritis
  - Autoimmune disease
  - Body attacks healthy joint tissue resulting in inflammation and damage
- Achondroplasia
  - Reduced proliferation of chondrocytes in growth plate
  - Results in form of dwarfism
- Costochondritis
  - Inflammation of cartilage in ribs that causes chest pain
- Herniated disc
  - Intervertebral disc rupture of cartilage ring
  - Disc herniates into spinal canal
- ***Interesting Fact***: *Cartilage prevents entry of lymphocytes and other molecules that contribute to rejection – so cartilage can be transplanted*

Types of cartilage



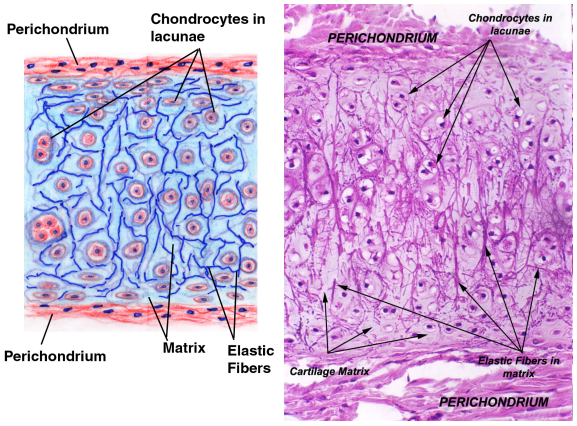
Ground substance = PGs, H2O, other small molecules excluding collagen

Basic Function
(more detail on next slides)

- Hyaline
  - Cover joints, lubricate, cushion
- Fibrous
  - Tensile strength
- Elastic
  - Maintain shape

http://www.botany.uwc.ac.za/Sci_Ed/grade10/mammal/cart.htm

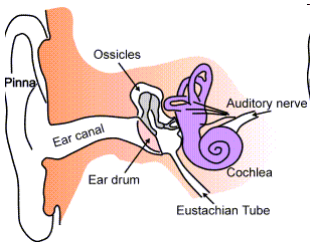
Elastic cartilage function is to maintain shape

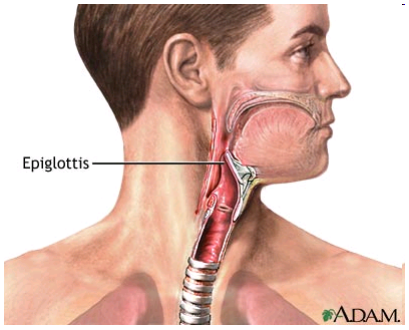


http://education.vetmed.vt.edu/curriculum/vm8054/Labs/Lab7/lab7.htm

- Found in pinna of ear (outside of ear), eustachian tube, other auditory canals, epiglottis, front of rib cage - – need specific shape in order to function
- Type II collagen and dense network of elastin fibers
- Matrix volume is less
- Fibers are elastic fibers with less collagen – deform and return to shape!

Epiglottis is a flap of cartilage located in the throat behind the tongue and in front of the larynx. **Eustacian tube** is a canal in ear.

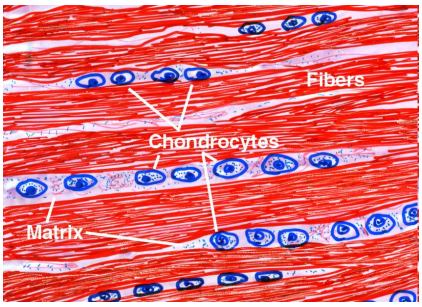


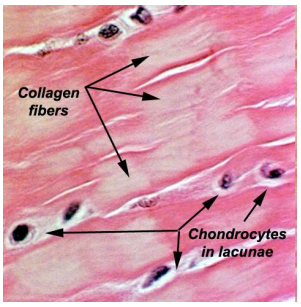


http://upload.wikimedia.org/wikipedia/commons/a/a7/Ear-anatomy-text-small-en.png

http://health.allrefer.com/pictures-images/epiglottis.html

Fibrocartilage function is to provide tensile strength or tough support





education.vetmed.vt.edu/curriculum/vm8054/Labs/Lab7/lab7.htm

- limited distribution in body: intervertebral disks, covering mandibular condyle in temporomandibular joint, meniscus of knee, and temporarily at bony fracture sites.
- tough, elastic, but not super elastic - similar to fibrous connective tissue
- directional
- collagenous fibers, not much ground substance matrix
- looks like connective tissue – can tell is cartilage because of chondrocytes
- cells embedded between fibers, fewer cells

Hyaline cartilage (also called articular cartilage, AC) covers diarthoidal joints covering long bones– we will focus here…

Diarthroidal joints = movable articulations

Healthy knee

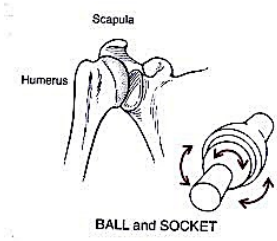
Osteoarthritic knee

- Cartilage becomes rough, thin
- Ends of bone thicken
- Joint may loose normal shape
- Joint ends may rub and cause pain

orthoinfo.aaos.org/

Mechanical function of AC

- To allow relative movement between articular surface with minimal friction
- To distribute forces in joints
- To transfer forces between articulating bones

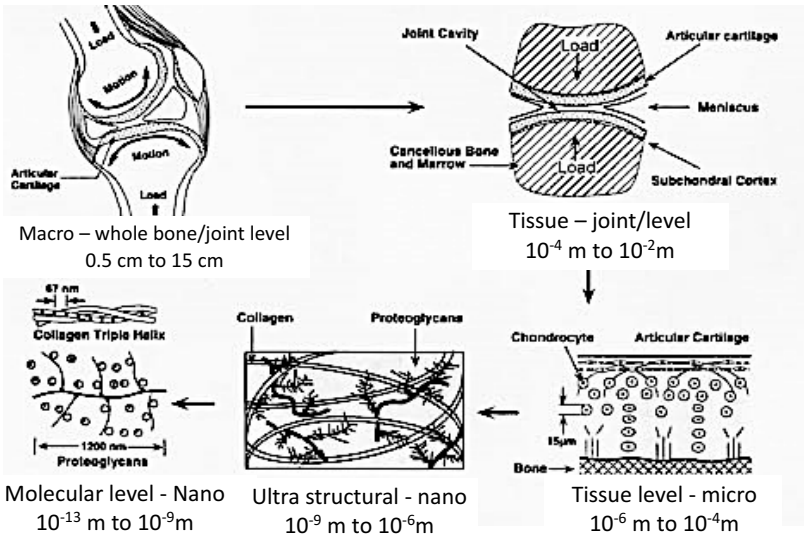


Physiologic function of AC

- Fluid component is a reservoir of gas, nutrients, ions, which allows for transport with motion
- Nutrient and waste transport
  - By diffusion and fluid flow
  - Compressive loading moves waste and nutrients
  - Inactivity is not good for articular cartilage!

The hierarchy of structures for articular cartilage

(know lengthscales) (coll-PG interactions very important to mechanical behavior)

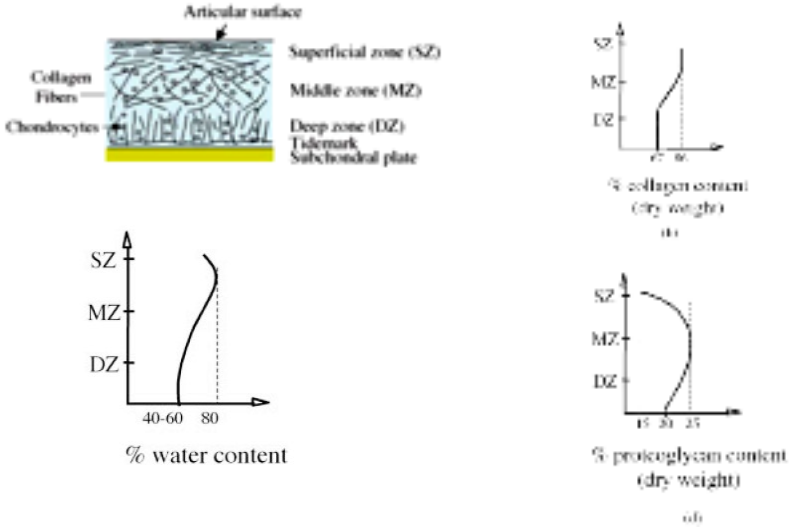


BME 456, umich, 2001

Articular cartilage is mostly water with collagen Type II and proteoglycans as the solid components.

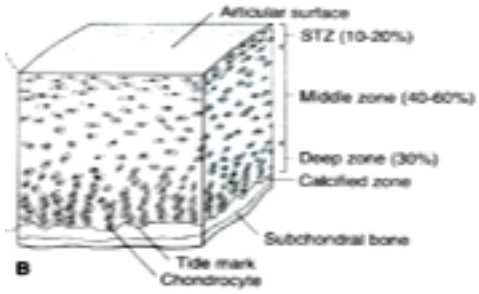
- 60-85% is water, salts, and other small matrix proteins
- 10-30% coll Type II by wet wt (50-75% by dry wt)
- 3-10% PGs by wet wt (15-30% by dry wt)
- Chondrocytes <10% of tissue volume (considered low cellular density)
- Proteoglycans
  - hold ~70% of the water,
  - coll Type II holds other ~30%.
- Collagen fibers are striated 15-45 nm in diameter but do not arrange into bundles like in other tissue

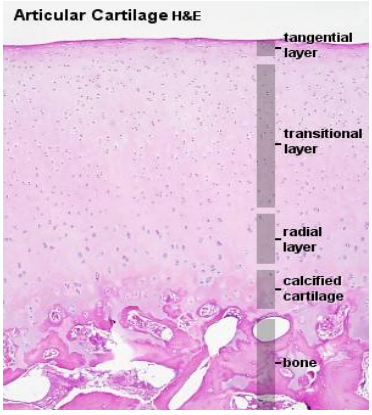
Composition varies with depth in articular cartliage – think about how **properties** vary with depth



Mow and Guo, Annu Rev Biomed Eng, 2002, 4:175-209

Chondrocyte arrangement and morphology varies through depth

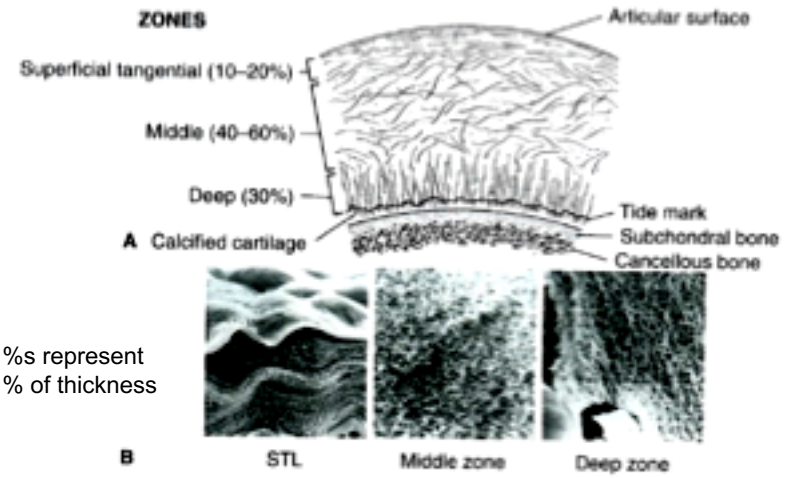




Nordin and Frankel 3-1

www.lab.anhb.uwa.edu.au/mb140/CorePages/Cartilage/Cartil.htm#CARTILAGE

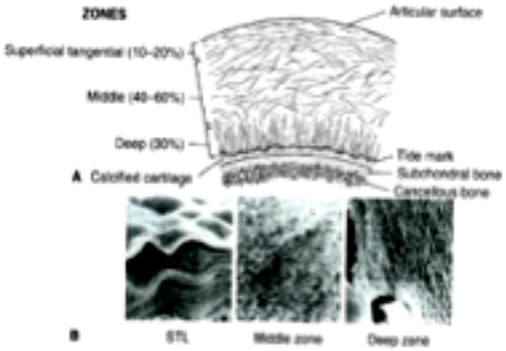
Fiber arrangement varies through depth



%s represent
% of thickness

 Nordin and Frankel 3-3

Fiber arrangement varies through depth



%s represent % of thickness

- STZ – fine, densely packed, woven fibers, parallel to articular surface
  - low PG content, low permeability to fluid flow
- MZ – less densely packed, randomly oriented, larger fibrils
  - PG content 10-25% dry wt,
  - high swelling pressure,
  - high water content
- DZ – fibers form radially oriented bundles,
  - lower PG content
  - Fibers cross tidemark and enter calcified cartilage Why?

 Nordin and Frankel 3-3