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M1 Musculoskeletal Sequence
Medical Histology

Cartilage / Mature Bone

Fall 2008
Cartilage

Cartilage is a specialized form of firm and resilient connective tissue that can bear stresses without permanent distortion.

It consists of **cells** (chondroblasts, chondrocytes) and extracellular matrix, consisting of **fibers** and **ground substance** (hyaluronic acid, proteoglycans, glycoproteins).

It is an avascular tissue.

It serves as a precursor or model for the embryonic development and subsequent growth of many long bones. (It is replaced by bone tissue in adult life, except for the surfaces that articulate with other bones.)
There are three types of cartilage:

- **Hyaline cartilage** (Type II collagen)
  Articular surfaces, Ephiphyseal plate, Tracheal wall, etc.

- **Elastic cartilage** (Type II collagen, elastic fibers)
  Pinna of the ear, Epiglottis, Eustachian tube, etc.

- **Fibrocartilage** (Type II and Type I collagen)
  Intervertebral disks, Pubic symphysis, insertion sites of tendons and ligaments
Stem cells

Chondroblast

Chondrocyte
Initiation of Cartilage Formation
(embryonic mesenchymal cells)
Beginning of cartilage Formation

- **Chondroblasts**
- **Perichondrium**
- **Perichondrial fibroblasts (osteogenic progenitor cells)**

Source Undetermined
Differentiation of chondrogenic cells

Perichondrium

Chondroblasts

Chondrocytes

Isogenous group

Lacuna

Isogenous group
Formed Hyaline Cartilage
Formed Hyaline Cartilage

- Perichondrium
- Chondroblasts
- Chondrocytes

Interstitial growth

(Appositional growth)
Cartilage growth

Appositional Growth: Deposition of new cartilage on the surface of existing cartilage.

Interstitial Growth: Formation of new cartilage within an existing cartilage.
Hyaline cartilage

Most common types of cartilage.

Nasal septum, larynx, tracheal rings, sternal ends of ribs, most articular surfaces and forms the template for developing long bones.
Tracheal Hyaline Cartilage

- **Chondroblasts**
- **Chondrocytes**
- **Perichondrium**

*Netter 2nd Ed. Plate 190*
Articular Cartilage
(Specialized form of hyaline cartilage)

Femoral head

Articular cartilages
Articular (hyaline) Cartilage in Joints
Cartilage Matrix

- Type II collagen
- Hyalurunan (hyaluronic acid) up to $8 \times 10^6$ d
- Proteoglycans ($3.5 \times 10^6$ daltons)
  - Aggrecan
    - Proetin Core
    - Glycosaminoglycans (GAGs)
      - Chondroitin sulfate
      - Keratin sulfate
Hyaline Cartilage Matrix

Core Protein
Type II Collagen
Core Protein

Synthesis of Matrix Components
Proteoglycans + HU and collagen
Sugars sulfate
Protein synthesis
Amino acids

Chondrocyte
Proteoglycan Aggregates

Consist of:

1. An axial hyaluronan (HU) molecule.
2. Core proteins attached to the HU molecule by a linker protein.
3. Glycosaminoglycans attached to a core protein.

Kierszenbaum, p. 108

EM view of spread preparation
Glycosaminoglycans
Extended random coil conformation of a single molecule of hyaluronan
Cartilage Matrix and It’s function

The glycosaminoglycans (GAGs) tend to adopt highly extended, so called random coil conformations, which occupy a huge volume relative to their mass and they form gel.

Their high density of negative charges attract cations, such as Na\(^{++}\) that are osmotically active causing large amounts of water to be sucked into the matrix.

This creates a swelling pressure or turgor, that enables the matrix to withstand compressive forces (in contrast to collagen fibers which resist stretching forces).

Cartilage matrix resist compression by this mechanism.

[Alberts: p804]
Basophilia in hyaline cartilage matrix

The basophilia in the matrix is due to the high density of negative charges in the GAG subunits, which attract the positive dye, hematoxylin.
Diarthrosis and Articular Cartilage

Bathed in synovial fluid.

No perichondrium
Collagen fibers - arranged as gothic arches
Chondrocytes - in vertical rows.
Articular cartilage

Perichondrium is absent
Cartilage Damage
Cartilage Changes with Aging

Not much changes with collagen.

The proteoglycans produced in older individuals are smaller with shorter chondroitin sulfate chains than in younger individuals.

Chondrocytes seem less efficient in renewing the matrix thus reducing proteoglycan contents.

These changes might reduce water contents in the matrix and make the cartilage less able to resist compressive forces.

These changes, in turn, would make matrix more vulnerable to injuries in weight-bearing, and the inflammatory response to injury would cause painful symptoms of arthritis.
Differences in basophilic staining in cartilage matrix

The difference in basophilic staining reflects the relative matrix content of glycosaminoglycans (aggrecans).

The decrease in size of proteoglycans or the length of chondroitin sulfate chains will reduce the relative matrix content of glycosaminoglycans. This, in turn, will reduce the intensity of basophilic staining in the cartilage matrix.
Elastic cartilage: contains elastic fibers.
Pinna of the external ear, auditory canal, epiglottis, Eustachian tube.

Fibrocartilage: intermediate between cartilage and dense regular connective tissue. Intervertebral discs, pubic symphysis, etc.
Elastic Cartilage

H&E stain

Weigert’s stain

Aldehyde Fuchsin

Michigan Medical School Histology Slide Collection
Fibrocartilage

Type I and II collagen. No identifiable perichondrium.
Elastic Cartilage and Fibrocartilage

Collagen I
Collagen II

Elastic fibers

Collagen II

Rhodin p.181

Source Undetermined
Bone

Cells: Osteoblasts, Osteocytes, Osteoclasts

Fibers: Type 1 Collagen

Bone Matrix:
  Ground Substance
  GAGs: Hyaluronan, Chondroitin & Keratan Sulfate
  Proteoglycans: short core proteins and relatively fewer GAG side chains than in cartilage.
  Hydroxyapatite crystals $[\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2]$: Calcium phosphate
<table>
<thead>
<tr>
<th>Cartilage</th>
<th>Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content: ~70%</td>
<td>Water content: 25%</td>
</tr>
<tr>
<td>Collagen II: ~40% of</td>
<td>Collagen I: 90% of</td>
</tr>
<tr>
<td>organic content.</td>
<td>organic content.</td>
</tr>
</tbody>
</table>

Other Ground Substance

- **Osteonectin**: anchor collagen to bone mineral.
- **Osteocalcin**: Calcium binding protein involved in bone calcification.
- **Osteopontin**: Binding of osteoblasts and osteoclasts to bone.

Grows interstitially and by apposition.  
Avascular

Grows only by apposition.  
Highly vascular
Bone

Provides support for the soft tissues of the body.

Provides sites for attachment of the muscles and tendons essential for locomotion.

Protects the vital organs of the cranium and various body cavities.

Encloses blood-forming elements in the bone marrow.

Plays an important role as a mobilizable store of calcium and phosphate.
Types of Bone
(Flat, long, short and irregular bones)
Compact (dense) and Spongy (cancellous) Bone

- Compact bone
- Cancellous bone

Head

Weiss, 6th ed., p. 218
Ross et al., 4th ed., p. 182
Long Bone

Epiphysis
Metaphysis
Diaphysis

Articular cartilage
Epiphyseal line
Sponge bone
Marrow cavity
Periosteum
Compact bone
Sponge bone
Epiphyseal line
Articular cartilage

Epiphyseal artery
Metaphyseal artery
Periosteal arteries
Nutrient artery
Compact bone

BLOOD SUPPLY OF ADULT LONG BONE

Ross et al., 4th ed., p. 182 & 185 (Both images)
Wall of a Long Bone

Helical course of collagen fibers
Haversian system (osteon)
Inner circumferential lamellae
Outer circumferential lamellae
Volkmann's canal
Blood vessel
Endosteum
Haversian canal
Periosteum
Haversian system (osteon), Haversian canal (HC) and Volkmann’s canal (VC)
Haversian system (osteon) / Harversian canal
Haversian Canal and Canaliculi
Osteocytes, Lacunae and Canaliculi
Osteocyte

Bloom & Fawcett, 12th ed. P. 208

Unmineralized matrix

Mineralized matrix
Osteocyte and its Process
Compact and Cancellous Bone
Sponge (cancellous) bone

Bone Marrow

Cancellous bone
Bone cells

Osteoblasts
Active
Inactive
Osteocytes
Osteoclasts

Howship’s lacuna (resorption bay)
Periosteum and Endosteum

- **Endosteum**
- **Fibrous layer of Periosteum**
- **Cellular layer of Periosteum**
- **Muscle**

Source Undetermined (Both images)
Learning Objectives

Cartilage

• Be able to recognize the three major cartilage types in light microscopic sections and know where in the body each type occurs.

• Be able to identify cells and structures in a section of cartilage (e.g. chondroblast, chondrocyte, lacuna, isogenous group, two type of matrix, perichondrium, etc).

• Know the contents of cartilage matrix and understand the molecular basis for resilience of cartilage.

• Be able to describe the process of chondrogenesis and know how cartilage grows.

• Understand what changes occur with aging in the matrix.
Learning Objectives

- **Adult Bone**
  - Be able to recognize compact and cancellous bone in conventional and ground sections and know the structural differences in the two types.
  
  - Be able to identify the component parts of adult bone and know their functions (e.g. periosteum, endosteum, osteon, canaliculus, lacuna, osteocyte, Haversian and Volkmann canal).
  
  - Be able to recognize the cells in adult bone at the light and EM level and know their functions (e.g. active and inactive osteoblasts, osteocytes, osteoclasts).
  
  - Know the major differences in matrix contents of cartilage and bone.
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Slide 18: Source Undetermined
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Slide 21: Kierszenbaum, p. 108; Albert et al., 2nd ed. p. 804
Slide 22: Albert et al., 2nd ed. p. 807; Albert et al., 2nd ed. p. 804
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Slide 46: Bloom & Fawcett, 12th ed. p. 206-7
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