Cartilage and Bone Lecture Objectives

• Describe the general functions of cartilage and bone.
• Compare the function and composition of the three types of cartilage.
• Describe the two methods of cartilage formation.
• Describe the cells and extracellular matrix of bone.
• Compare and contrast primary and secondary bone.
• Describe the two methods of bone formation.
Cartilage and Bone Lecture Outline

Cartilage

• Function and characteristics of cartilage
• Composition of cartilage
• Three types of cartilage
• Formation of cartilage

Bone

• Function and characteristics of bone
• Composition of bone
• Four types of bone
• Formation of bone
Cartilage and Bone Lecture Outline

Cartilage

- Function and characteristics of cartilage
Functions and Characteristics of Cartilage

• Cartilage is strong and sort of rigid but also flexible. It can withstand force but it can also bend.

• It’s made of cells (chondroblasts and chondrocytes) and extracellular matrix.

• Forms the supporting framework of some organs.

• Lines the surface of articulating bones.

• Forms the template for growth and development of long bones.
Metabolic facts that will make you feel sorry for cartilage

• Bone is very metabolically active. Cartilage is not.
• Bone has a good blood supply. Cartilage does not.
• Bone usually heals well. Cartilage does not.
Cartilage and Bone Lecture Outline

Cartilage

• Function and characteristics of cartilage
• Composition of cartilage
Cartilage Cells

**Chondroblasts**
Precursor cells that differentiate into chondrocytes.

**Chondrocytes**
Mature cartilage cells that lie in little artifactual lacunae.
Cartilage Extracellular Matrix (ECM)

Cartilage ECM is composed of:
- Fibers
- Lots of GAGs and proteoglycans

Nice choices! These substances make the ECM firm and resistant to mechanical forces.
Composition of ECM in Cartilage
Glycosaminoglycans (GAGs) are disaccharide chains.

Hyaluronic acid (really long, not bound to a core protein).

All the other GAGs (shorter, always bound to a core protein).

Proteoglycans have a protein core with a bunch of attached GAGs.
Perichondrium covers the surface of elastic cartilage and non-articular hyaline cartilage.

- Dense connective tissue composed of fibroblasts and type I collagen fibers.
- Contains blood vessels.
Cartilage is avascular. So what?

- Cartilage itself has no blood vessels or nerves in its extracellular matrix (bone is a different story).
- Nutrients must diffuse from perichondrium through extracellular matrix to chondrocytes.
- This means metabolic activity is low, the width of cartilage is limited, and cartilage heals poorly.
Cartilage and Bone Lecture Outline

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• Function and characteristics of cartilage
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The fibers of the extracellular matrix determine the type of cartilage.

**Hyaline cartilage**
- Type II collagen

**Elastic cartilage**
- Type II collagen
- Elastic fibers

**Fibrocartilage**
- Type I collagen
- $\pm$ Type II collagen
Hyaline Cartilage

- Most common type of cartilage in the body
- Type II collagen fibers give ECM a glassy appearance
- Supports large respiratory airways (trachea, bronchi)
- Lines bone surfaces in articulating joints
- Important part of the epiphyseal plate
Hyaline cartilage

- chondrocytes
- matrix

Hyaline cartilage
Isogenous group

Hyaline cartilage
Hyaline cartilage (trachea)

Tracheal epithelium

Perichondrium

Cartilage

Hyaline cartilage (trachea)
Hyaline cartilage (articular surface of bone)

No perichondrium!
Hyaline cartilage (epiphyseal plate)
Elastic Cartilage

- Resembles hyaline cartilage – but also has elastic fibers
- Great for places that need more flexible support
- External ear, auditory tubes, epiglottis
Elastic cartilage (outer ear)
Elastic fibers

Elastic cartilage
Elastic cartilage (silver stain)
Fibrocartilage

- Tons of type I collagen
- ...and sometimes a little type II collagen
- Provides a super strong connection in places that are subject to pulling forces
- Pubic symphysis, intervertebral disks, attachments of tendons and ligaments
Isogenous group

Fibrocartilage
The next slide is also fibrocartilage, but it would be criminal to mess it up with labels. Notice the type I collagen (pink) and hints of type II collagen (glossy lavender).
Same thing with the next two slides! Fibrocartilage, stained with a trichrome stain, which colors collagen fibers a pretty blue.
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Two Methods of Cartilage Formation

**Interstitial growth**: growth from within cartilage. Chondrocytes divide and secrete matrix.

**Appositional growth**: growth along the outside of cartilage. Chondroblasts secrete matrix and differentiate into chondrocytes.
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Bone
• Function and characteristics of bone
Functions of Bone

• Support and protection of soft tissues
• Attachment of muscles for movement
• Location of hematopoietic bone marrow where blood cells are produced
• Stores and releases calcium, phosphate and other ions
Characteristics of Bone

• Bone is highly vascularized and very metabolically active.

• Bone remodels (turns over) constantly throughout life. Ideally, bone removal occurs at same rate as bone production.

• Inhibition of bone turnover leads to poor quality, unhealthy bone.
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Bone
• Function and characteristics of bone
• Composition of bone
Composition of Bone

Cells

- Osteoblasts: produce bone matrix
- Osteocyttes: sit in lacunae
- Osteoclasts: resorb bone

Extracellular matrix

- Organic part: type I collagen and ground substance
- Inorganic part: minerals (calcium and phosphate)
Osteoblasts

• Found along edges of bone.
• Make matrix!
  • First, produce organic part (type I collagen and ground substance). This is called “osteoid” before it’s mineralized.
  • Then, add the inorganic part (minerals).
• As osteoblasts become surrounded by matrix, they turn into osteocytes.
Osteoblasts
Osteocytes

- Sit in little lacunae (spaces) completely surrounded by matrix.
- Involved in maintenance of matrix (if osteocytes die, matrix dissolves).
- Otherwise, they don’t do much.
Osteocytes
Osteoclasts

• Gigantic multinucleated cells derived from monocytes.
• Sit on bone surface in little indentations called “Howship’s lacunae.”
• Chew up (resorb) bone.
• When active, have a “ruffled” cytoplasmic border next to the bone.
Osteoclasts
Osteoclasts destroy bone in a nasty little microenvironment filled with acid and collagenase. A nice protective zone surrounds and seals off the acidic microenvironment.
Serum Calcium and Bone Resorption

When serum calcium is low, parathyroid hormone is released, which tells osteoblasts to make osteoclast stimulating factor. Osteoclasts then resorb bone, which increases serum calcium. Cool!

When serum calcium is high, calcitonin is released, which inhibits osteoclastic resorption of bone, leading to decreased serum calcium.
Bone Matrix

Organic part
• Type I collagen and ground substance
• Called “osteoid” before it’s mineralized

Inorganic part
• 50% of dry weight of bone
• Minerals (mostly calcium; some phosphate)
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Four Types of Bone

Compact bone
Outer surfaces of bones. Dense, solid structure.

Spongy bone
Inside bones. Open, loose structure.

Primary (immature, woven) bone
First bone tissue formed during growth or repair. Irregular arrangement of collagen fibers.

Secondary (mature, lamellar) bone
Replaces primary bone. Contains osteons with parallel arrangement of collagen fibers.
Compact Bone and Spongy Bone
Primary bone
Secondary bone

Lamellae

Central canal

Osteocytes

Secondary bone
Osteon (Haversian system)
Volkmann (perforating) canals connect osteons
Periosteum and Endosteum

Periosteum lines the outer surface of compact bone.

- Two layers: outer dense connective tissue layer and inner layer of osteoprogenitor cells.
- Sharpey’s fibers are collagen fibers which tightly attach the periosteum to the bone matrix.
- Contains blood vessels for nutrition of bone.
- Contains osteoblasts for bone growth, repair and remodeling.
Periosteum
- outer layer
- inner layer
- perforating fibers
- external lamellae
- central canal
- osteon
- interstitial lamellae
- trabeculae of spongy bone
Periosteum and Endosteum

Periosteum lines the outer surface of compact bone.

Endosteum lines the inner surface of compact bone.

- Also lines the surface of bony trabeculae of spongy bone, and the Haversian canals.
- Contains osteoblasts for bone growth, repair and remodeling.
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Bone Development (Osteogenesis)

Bone can be formed in two ways:

**Intramembranous ossification**
Occurs in flat bones.

**Endochondral ossification**
Occurs in long bones.
Intramembranous Ossification

Ossification centers form within thickened regions of mesenchyme.

- Collagen fiber
- Mesenchymal cell
- Ossification center
- Osteoid
- Osteoblast
Intramembranous Ossification

Osteoid undergoes calcification.

- Osteoid
- Osteoblast
- Osteocyte
- Newly calcified bone matrix
Intramembranous Ossification

Woven bone and surrounding periosteum form.

- Mesenchyme condensing to form the periosteum
- Blood vessel
- Trabecula of woven bone
Intramembranous Ossification

Lamellar bone replaces woven bone, as compact and spongy bone form.
Endochondral Ossification

1. Fetal hyaline cartilage model develops.
2. Cartilage calcifies, and a periosteal bone collar forms around diaphysis.
Endochondral Ossification

1. Blood vessel of periosteal bud
2. Epiphyseal blood vessel
3. Primary ossification center forms in the diaphysis.
4. Secondary ossification centers form in epiphyses.
Endochondral Ossification

**Epiphysis**: the end of a long bone. Consists primarily of spongy bone, with a layer of compact bone on the outside.

**Diaphysis**: the shaft of a long bone. Consists of compact bone on the outside and a marrow cavity inside.
Epiphyseal plate: super low-power view
Zones of the epiphyseal plate

<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zone of resting cartilage</td>
</tr>
<tr>
<td>2</td>
<td>Zone of proliferating cartilage</td>
</tr>
<tr>
<td>3</td>
<td>Zone of hypertrophic cartilage</td>
</tr>
<tr>
<td>4</td>
<td>Zone of calcified cartilage</td>
</tr>
<tr>
<td>5</td>
<td>Zone of ossification</td>
</tr>
</tbody>
</table>
Epiphyseal plate
Epiphyseal plate: resting zone
Epiphyseal plate: proliferative zone
Epiphyseal plate: zone of hypertrophy
Epiphyseal plate: zone of calcification
Epiphyseal plate: zone of ossification
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