CARTILAGE, BONE AND OSTEOGENESIS

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Objectives

• Histologically identify and functionally characterize each of the various forms of supporting connective tissue.

• Recognize the structure and characterize the function of cells, fibers and ground substance components of each of the supporting connective tissues examined.

• Describe the cellular mechanisms that provide for intramembranous and endochondrial bone development.

• Compare and contrast the structure and function of compact and sponge bone.

From: Douglas P. Dohrman and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems, Histology Laboratory Manual
FUNCTIONS OF CARTILAGE

FLEXIBLE SUPPORT - RETURN TO ORIGINAL SHAPE (EARS, NOSE, AND RESPIRATORY)
FUNCTIONS OF CARTILAGE

SLIDES ACROSS EACH OTHER EASILY WHILE BEARING WEIGHT (JOINTS, ARTICULAR SURFACES OF BONES)

CUSHION - CARTILAGE HAS LIMITED COMPRESSIBILITY (JOINTS)

No nerves and, thus, no pain during compression of cartilage.
CONNECTIVE TISSUE

Connective tissue proper

Connective tissue with special properties

Supporting connective tissues

Loose (areolar)

Dense
- Regular
- Irregular

Adipose tissue (Chapter 6)
Elastic tissue
Hematopoietic (lymphatic and myeloid) tissue (Chapter 14)
Mucous tissue

Cartilage (Chapter 7)
Bone (Chapter 8)
CELLS OF CT

FIBROBLASTS
MESENCHYMAL
CELLS and RBC
ADIPose CELLS
MACROPHAGE
PLASMA CELLS
MAST CELLS and WBC

CHONDROBLASTS
CHONDROCYTES

OSTEOBLASTS
OSTEOCYTES
OSTEOCLASTS
GENERAL ORGANIZATION OF CARTILAGE

PERICHONDRIUM

CAPSULE-LIKE SHEATH OF DENSE IRREGULAR CONNECTIVE TISSUE THAT SURROUNDS CARTILAGE (EXCEPT ARTICULAR CARTILAGE)

FORMS INTERFACE WITH SUPPORTED TISSUE

HARBORS A VASCULAR SUPPLY
GENERAL ORGANIZATION OF CARTILAGE

MATRIX

TYPE II COLLAGEN (LACK OF OBVIOUS PERIODICITY)
GENERAL ORGANIZATION OF CARTILAGE

MATRIX

TYPE II COLLAGEN (LACK OF OBVIOUS PERIODICITY)

SULFATED PROTEOGLYCANS (CHONDROITIN SULFATE AND KERATAN SULFATE) - STAIN BASOPHILIC
GENERAL ORGANIZATION OF CARTILAGE

MATRIX

TYPE II COLLAGEN (LACK OF OBVIOUS PERIODICITY)

SULFATED PROTEOGLYCANS (CHONDROITIN SULFATE AND KERATAN SULFATE) - STAIN BASOPHILIC

CAPABLE OF HOLDING WATER / DIFFUSION OF NUTRIENTS

AVASCULAR - GETS NUTRIENT/WASTE EXCHANGE FROM PERICHONDRIUM
GENERAL ORGANIZATION OF CARTILAGE

CHONDROCYTES / CHONDROBLASTS
GENERAL ORGANIZATION OF CARTILAGE

CHONDROCYTES / CHONDROBLASTS
GENERAL ORGANIZATION OF CARTILAGE

CHONDROCYTES / CHONDROBLASTS
GENERAL ORGANIZATION OF CARTILAGE

CHONDROCYTES / CHONDROBLASTS

Type II collagen fibril
Hyaluronic acid
Proteoglycan
Core protein
Collagen (type II)

Proteoglycans and collagen
Sugars sulfate

Chondroitin sulfate
Link protein
Cartilage

- **Hyaline cartilage**
  - Glassy matrix (GAGs, proteoglycans, collagen II) devoid of blood vessels, surrounded by fibrous sheath perichondrium

- **Elastic cartilage**
  - Similar to hyaline except chondrocytes become trapped in their secretions (enmeshed within the matrix, lacunae), has elasticity thus maintains its shape

- **Fibrocartilage**
  - Course collagen I fibers form dense bundles to withstand physical stresses, strengthen hyaline cartilage
Developing Cartilage

Cartilage grows by both interstitial growth (mitotic division of preexisting chondroblasts) and by appositional growth (differentiation of new chondroblasts from the perichondrium).
Slide 40: Trachea

- Hyaline cartilage
- C-ring
- Chondrogenic region
- Chondroblasts
- Isogenous group of chondrocytes in individual lacunae
- Territorial matrix
- Inter-territorial matrix
- Perichondrium
Staining variations within the matrix reflect local differences in its molecular composition. Immediately surrounding each chondrocyte, the ECM is relatively rich in GAGs causing these areas of territorial matrix to stain differently from the intervening areas of interterritorial matrix.
Elastic cartilage has obvious elastic fibers in an otherwise heterogenous matrix with more individual cells and fewer isogenous groups.
Slide 16: External auditory tube (Verhoeff’s stain for elastin)

- Elastic fibers
- Perichondrium
- Chondrocyte
- Lacunae
FIBROCARTILAGE

INTERMEDIATE BETWEEN DENSE REGULAR CONNECTIVE TISSUE AND HYALINE CARTILAGE

NO PERICHONDRIUM
FIBROCARTILAGE

FOUND IN:

- INTERVERTEBRAL DISCS
- ATTACHMENT OF LIGAMENTS TO CARTILAGINEOUS SURFACE OF BONES
Slide 17: Vertebra

- Hyaline cartilage
- Fibrocartilage
- Dense connective tissue
- Chondrocyte in lacunae
- Bone
- Fibrocartilage
- Hyaline cartilage
Fibrocartilage of Fetal elbow

Fibrocartilage
Fibrocartilage of Fetal elbow
Fetal finger – fibroblasts in tendon
Fetal finger – fibroblasts in tendon

Tendon

Fibrocartilage
SUMMARY OF CARTILAGE

HYALINE

FIBROCARTILAGE

ELASTIC
SUMMARY OF CARTILAGE

HYALINE

ELASTIC

FIBROCARTILAGE
FUNCTIONS OF BONE

SKELETAL SUPPORT
LAND ANIMALS

PROTECTIVE ENCLOSURE
SKULL TO PROTECT BRAIN
LONG BONE TO PROTECT
HEMOPOIETIC CELLS
FUNCTIONS OF BONE

CALCIUM REGULATION

Parathyroid hormone (BONE RESORPTION)
FUNCTIONS OF BONE

CALCIUM REGULATION

Parathroid hormone (BONE RESORPTION)

Calcitonin (PREVENTS RESORPTION)

These HORMONES are INVOLVED IN TIGHT REGULATION as 1/4 OF FREE CA^{++} IN BLOOD IS EXCHANGED EACH MINUTE.
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HEMOPOIESIS
CELLS OF BONE

OSTEOBLASTS - SECRETE OSTEOID - BONE

- EXPAND BONE BY APPOSITIONAL GROWTH
CELLS OF BONE

OSTEOBLASTS - SECRETE OSTEOID - BONE
- EXPAND BONE BY APPositionAL GROWTH

OSTEOCYTE = OSTEOBLAST TRAPPED IN MATRIX OF BONE
CELLS OF BONE

OSTEOBLASTS

OSTEOCYTES – OSTEOBLASTS TRAPPED IN MATRIX OF BONE
CELLS OF BONE
OSTEOCLASTS - MULTINUCLEATED PHAGOCYTIC CELLS
FROM MONOCYTES
CELLS OF BONE
OSTEOCLASTS - MULTINUCLEATED PHAGOCYTIC CELLS FROM MONOCYTES
Slide 17: Vertebra

- Fibrous periosteum containing fibroblasts
- Cancellous bone
- Osteocyte in lacunae
- Osteoblasts lining bony trabeculae
Developing Bone

Methods of bone development

- **Intramembranous**: formation within fibrous/collagenous membranes. Formation fibroblast like precursor cells

- **Endochondrial ossification**: formation within cartilage model with distinct zones of development, formation by replacing cartilage cells and matrix
HISTOGENESIS OF BONE

INTRAMEMBRANOUS OSSIFICATION

DIRECT MINERALIZATION OF MATRIX SECRETED BY OSTEOBLAST WITHOUT A CARTILAGE MODEL
HISTOGENESIS OF BONE

INTRAMEMBRANOUS OSSIFICATION

FLAT BONES OF SKULL
Slide 36: Nasal septum (intramembranous osteogenesis)

- Osteoblasts
- Osteoclasts in Howship’s lacunae
- Bone spicule
HISTOGENESIS OF BONE

ENDOCHONDRLAL OSSIFICATION

DEPOSITION OF BONE MATRIX ON A PREEXISTING CARTILAGE MATRIX
CHARACTERISTIC OF LONG BONE FORMATION
Slide 20: Long bone (longitudinal section; epiphysial plate)
EXTRACELLULAR MATRIX OF BONE

OSTEOID - MIXTURE OF TYPE I COLLAGEN AND COMPLEX MATRIX MATERIAL TO INCREASE THE AFFINITY AND SERVE AS NUCLEATION SITES FOR PARTICIPATION OF CALCIUM PHOSPHATE (HYDROXYAPATITE)
EXTRACELLULAR MATRIX OF BONE

SECRETED by POLARIZED OSTEOBLASTs

CALCIFICATION - ADDS FIRMNESS, BUT PREVENTS DIFFUSION THROUGH MATRIX MATERIAL
EXTRACELLULAR MATRIX OF BONE

FORMS LACUNAE AND CANALICULI -
EXTRACELLULAR MATRIX OF BONE

FORMS LACUNAE AND CANALICULI - CAUSES THE NEED FOR NUTRIENTS TO PAST THROUGH THE MANY GAP JUNCTIONS BETWEEN OSTEOCYTES VIA CANALICULI
COMPACT BONE - SHAFT AND OUTER SURFACE OF LONG BONES
COMPACT BONE-SHAFT AND OUTER SURFACE OF LONG BONES

PERIOSTEUM
FIBROBLAST create
CIRCUMFERENTIAL LAMELLAE
• APPOSITIONAL GROWTH
COMPACT BONE-SHAFT AND OUTER SURFACE OF LONG BONES

PERIOSTEUM
FIBROBLAST create CIRCUMFERENTIAL LAMELLAE
• APPOSITIONAL GROWTH
(NOTE: BONE HAS NO INTERSITIAL GROWTH AS DOES CARTILAGE)
COMPACT BONE-SHAFT AND OUTER SURFACE OF LONG BONES

ENDOSTEUM - INSIDE COMPACT BONE, SURFACES OF SPONGY BONE, INSIDE HAUVERSIAN SYSTEMS
COMPACT BONE

HAVERSIAN SYSTEMS - LAMELLAE OF BONE AROUND HAVERSIAN CANAL LINKED BY VOLKMANN’S CANAL
Slide 19: Compact bone (ground cross section)

- Volkmann’s canal
- Canaliculi
- Concentric lamellae
- Osteon/Haversian systems
- Haversian canal
- Lacunae containing osteocyte
- Interstitial lamellae
Slide 19: Compact bone (ground cross section)

Connecting adjacent osteons, perforating (Volkmann’s) canals provide communication for osteons and another source of microvasculature for the central canals of osteons (nutrients, blood, etc.).
Clinical Correlation

An elderly patient is diagnosed with osteoporosis.

Describe the cells involved that produce this imbalance in bone production and resorption.

Which of these cell types would be more active and which would be less active?

What is the difference between osteoporosis and osteomalacia?
FUNCTIONS OF BONE

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Parathroid hormone (stimulates osteoclast production)
FUNCTIONS OF BONE

CALCIUM REGULATION

Parathroid hormone (stimulates osteoclast production)

Calcitonin (removes osteoclast’s ruffled boarder which PREVENTS RESORPTION)
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Osteoporosis is an imbalance in skeletal turnover so that bone resorption exceeds bone formation. This leads to calcium loss for bones and reduced bone mineral density.
FUNCTIONS OF BONE

CALCIUM REGULATION

Parathroid hormone (stimulates osteoclast production)

Calcitonin (removes osteoclast’s ruffled boarder which PREVENTS RESORPTION)

Osteoporosis is an imbalance in skeletal turnover so that bone resorption exceeds bone formation. This leads to calcium loss for bones and reduced bone mineral density.

Osteomalacia is characterized by deficient calcification of recently formed bone and partial decalcification of already calcified matrix.
Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

- Douglas P. Dohrman and TAMHSC Faculty 2012 Structure and Function of Human Organ Systems, Histology Laboratory Manual - Slide selections were largely based on this manual for first year medical students at TAMHSC