Chapter 6
Skeletal System

Tissues

- Cartilage
- Bone tissue
- Epithelium
- Nerve
- Blood forming tissue
- Adipose
- Dense connective tissue

Introduction to Skeletal System

Primary Functions

1. Support
2. Storage of minerals and lipids
   - Calcium
   - Phosphate
   - Lipids in yellow marrow
3. Blood cell production
   - Red marrow
4. Protection
5. Leverage

Gross Anatomy of Bones

Bones Shapes

Babies are born with 300 bones, but by adulthood we have only 206 in our bodies.

Bone Structure

- Diaphysis: shaft
- Epiphysis: end of long bone (contains spongy bone)
- Epiphyseal line: remnant of the epiphyseal plate
- Metaphysis: region between diaphysis and epiphysis
- Articular cartilage: hyaline cartilage on ends
- Periosteum: double layered membrane that covers the diaphysis
  - Connective tissue covering bone
  - Nourishment, growth, tendon/ligament attachment
- Medullary cavity: marrow cavity
- Endosteum: inner epithelial layer surrounding medullary cavity
Blood and Nerve Supply

- Periosteal vessels
  - supply periosteum
  - Superficial osteons
  - Secondary ossification centers
- Nutrient artery and vein
  - enter through nutrient foramen
  - supply compact bone of diaphysis & red marrow
- Metaphyseal & epiphyseal vessels
  - supply red marrow & bone tissue of epiphyses

Gross Anatomy of Bones
Bone Structure

- Flat Bone
  - Consist of two thin flat plates of compact bone enclosing a diploe
  - Diploe: internal layer of spongy bone
  - No medullary cavity
  - Short and irregular
  - Flat Bone bones resemble flat bones structurally

Bone Histology
Matrix

- Inorganic components
  - Hydroxyapatite: $Ca_{10}(PO_4)_6(OH)_2$
  - Calcium phosphate: $Ca(PO_4)_2$
  - Calcium hydroxide: $Ca(OH)_2$
  - Crystals incorporate other salts and ions
    - Calcium carbonate: $CaCO_3$
    - Sodium
    - Magnesium
    - Fluoride
  - Hard, inflexible, brittle
- Osteoid: Organic components
  - Collagen fibers and glycoproteins
  - Flexibility and strength

Histology of Bone
Cells

Types of cells in bone tissue
1. osteoprogenitor cells
2. osteoblasts
3. osteocytes
4. osteoclasts
Histology of Bone

Types of Cells

✓ Osteoprogenitor Cells
- Cells in endosteum, periosteum, and blood vessel canals
- Undifferentiated cells that give rise to osteoblasts and osteocytes
- Mitotic, can divide to replace themselves

✓ Osteoblasts
- Bone-forming cells, synthesize & secrete osteoid
- Osteoid: non-mineralized ground substance
- No mitosis
- Located on surface of bone
- Regulate movement of calcium/phosphorous into & out of bone

✓ Osteocytes
- Mature bone cells, derived from osteoblasts that have secreted bone tissue around them
- Secrete enzymes & influence bone mineral content (no longer secrete matrix)
- No mitosis
- Maintain bone tissue (osteoblasts trapped in lacunae)

✓ Osteoclasts
- Huge cells from fused monocytes (WBC) bone remodeling cells
- Osteolysis: enzymatically breakdown bone tissue
- Located on surface of bones

Histology of Bones

Bone Structure

✓ Compact bone: dense outer layer that looks smooth and solid to the naked eye
✓ Spongy bone: internal layer
  - Trabeculae: a honeycomb of small needle-like or flat pieces
Histology of Bone

Compact Bone

- **Function:**
  - Strength
  - Support

- **Location:**
  - Surfaces
  - Diaphysis

Spongy Bone

- **Location:**
  - Interior; ends of long bones, inside of flat bones

- **Function:**
  - Blood cell formation
  - Energy storage
  - Some support

No true Osteons
Bone Histology

Bone Marrow

- Red marrow
  - Contains hematopoietic cells - create RBCs, WBCs, platelets
  - In new born, all areas of spongy bone contain red bone marrow
  - In adults, red bone marrow found in heads of femur, humerus and in flat bones (sternum) and some irregular bones (pelvis)

- Yellow marrow
  - Adipose tissue
  - Energy reserve

Osteogenesis Imperfecta

“Brittle Bone Disease”

An inherited collagen disorder resulting in defects in the formation of bone

Bone Histology

Periosteum and Endosteum

- Periosteum: bilayer of connective tissue that covers all bones
  - Isolates bone from surrounding tissues
  - Provides routes for circulatory and nervous supply
  - Participates in bone growth and repair
  - Perforating fibers (sharpey's fibers)

- Endosteum: cellular layer that lines the marrow cavity

Bone Formation and Growth

- Ossification (Osteogenesis): the process of replacing other tissues with bone
  - Calcification: deposition of mineral salts during ossification

- Two types:
  - Endochondral ossification: formation of bone within hyaline cartilage
  - Intramembranous ossification: formation of bone directly from mesenchymal cells or fibrous connective tissue
Bone Development

Endochondral Ossification

- Epiphyseal plate or cartilage growth plate
  - cartilage cells are produced by mitosis on epiphyseal side of plate
  - cartilage cells are destroyed and replaced by bone on diaphyseal side of plate
- Between ages 18 to 25, epiphyseal plates close
  - cartilage cells stop dividing and bone replaces the cartilage (epiphyseal line)
- Growth in length stops at age 25

Bone Development

Intramembranous Ossification

- Blood capillary
- Center of ossification
- Mesenchymal cell
- Osteoblast
- Osteoid

- Formation of trabeculae
- Periosteum
- Hyaline cartilage
- Dense connective tissue

Growth in Length

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Zones of Growth in Epiphyseal Plate

- Zone of hypertrophy
- Zone of maturation
- Zone of calcification
- Zone of woven cartilage
- Zone of mature cartilage
- Zone of calcified cartilage
- Zone of bone matrix
Bone Development

Growth in width

- **Only by appositional growth at the bone's surface**
- **Periosteal cells differentiate into osteoblasts and form bony ridges and then a tunnel around periosteal blood vessel**
- **Concentric lamellae fill in the tunnel to form an osteon**

Dynamic Nature of Bone

Remodeling
Replacement of old bone tissue by new bone tissue

Dynamic Nature of Bone

Growth and Remodeling during Youth

- Bone grows in length
- Cartilage grows here
- Cartilage replaced by bone here
- Bone resolved here
- Bone added by appositional growth here
- Remodeling growth shaft is replaced by bone here
Dynamic Nature of Bone
Bone Remodeling Disorders

Paget's Disease

Osteoporosis

- Group of diseases in which bone reabsorption outpaces bone deposition
- As a result bone becomes more porous, lighter and weaker

Normal spongy bone

Osteoporosis

Effects of Exercise on Bone
Bone Anatomy and Stress

Hormonal and Nutritional Effects

- **Nutrition**
  - Calcium and phosphorus for bone growth
  - Calcitriol and cholecalciferol (vitamin D$_3$)
  - Vitamin C for collagen formation
  - Vitamins K and B12 for protein synthesis
  - Vitamin A stimulates osteoblasts

- **Sufficient levels of specific hormones**
  - During childhood need insulin-like growth factor
  - Promotes cell division at epiphyseal plate
  - Need IGF (growth), thyroid (T3 & T4) and insulin
  - Sex steroids at puberty
    - Growth spurt and closure of the epiphyseal growth plate
    - Estrogens promote female changes -- wider pelvis
Calcium

- Parathyroid Hormone (PTH)
  - raises blood Ca levels
  - acts on bones
  - increases osteoclast activity
  - acts on kidneys
    - decreases Ca loss in urine
    - increases P loss in urine
    - increases Calcitrol formation
- Calcitonin (CT)
  - from thyroid
  - lowers blood Ca levels
    - decreases osteoclast activity
    - increases Ca loss in urine
- Sex Hormones
  - estrogen maintains bone density

Bone Homeostasis
Fracture and Repair of Bone

- A fracture is any break in bone
- Often named for shape or position of fracture line
- Reduction: restore broken ends to normal position
- Fracture Repair may take months
  - factors
    - rate of mineral deposition
    - blood supply

Bone Scan

- Radioactive tracer is given intravenously
- Amount of uptake is related to amount of blood flow to the bone
- "Hot spots" are areas of increased metabolic activity that may indicate cancer, abnormal healing or growth
- "Cold spots" indicate decreased metabolism of decalcified bone, fracture or bone infection

Fractures and Repair

- Hematoma
  - Clot forms
  - Bone cells die
  - Inflammation
    - Lay down collagen
  - New capillaries
  - Fibroblasts and osteoprogenitors
  - Phagocytes and chondroblasts
- Soft callus
  - Fibrocartilage
- Bony callus
  - Vascularized areas
  - Compact bone
- Remodeling
  - Osteoblasts
  - Spongy bone
  - Remodeled osteoclasts
  - to normal shape
Fractures

Common types
- Degree of separation
  - partial (greenstick)
  - complete
- Degree of Exposure
  - closed (simple) -- no break in skin
  - open fracture (compound) -- skin broken
- comminuted -- broken ends of bones are fragmented
- impacted -- one side of fracture driven into the interior of other side

Examples of Common Fractures

- Origin
  - avulsion: tearing away
  - stress: compression force creating microscopic fissures
  - direct: force applied at fracture site
  - indirect: force transmitted via tissues to fracture site distant to application point
  - pathologic: weakness due to disease (e.g. osteoporosis)

Examples of Common Fractures

- shape or direction
  - depressed: bone pushed in
  - oblique
  - longitudinal
  - transverse
  - spiral
  - stellate: star shaped
  - fissure: usually involve only cortex of bone with the periosteum remaining intact
Examples of Common Fractures

- Fracture eponyms (named after a person or event)
  - Colle's: distal radius of wrist
  - Patt's: distal fibula fracture
  - Hangman's: cervical fracture caused by hyperextension of head as in auto accident
  - Saddle: fighters broken nose

Aging & Bone Tissue

- Bone is being built through adolescence, holds its own in young adults, but is gradually lost in aged.
- Demineralization = loss of minerals
  - very rapid in women 40-45 as estrogens levels decrease
  - in males, begins after age 60
- Decrease in protein synthesis
  - decrease in growth hormone
  - decrease in collagen production which gives bone its tensile strength
  - bone becomes brittle & susceptible to fracture

Axial Skeleton
- 80 bones
- lie along longitudinal axis
- skull, hyoid, vertebrae, ribs, sternum, ear ossicles

Appendicular Skeleton
- 126 bones
- upper & lower limbs
- and pelvic & pectoral

Bone Surface Markings
- Surface features -- rough area, groove, openings, process
- Specific functions
  - passageway for blood vessels and nerves
  - joint formation

Bone Tissue
- Build
- Hold
- Lose
- Minerals
- Estrogens
- Growth Hormone
- Collagen
- Tensile Strength
- Brittle
- Fracture
Bone Surface Markings

- Foramen = opening
- Fossa = shallow depression
- Sulcus = groove
- Meatus = tubelike passageway or canal
- Condyle = large, round protuberance
- Facet = smooth flat articular surface
- Trochanter = very large projection
- Tuberosity = large, rounded, roughened projection

The Skull

14 Facial Bones

- Nasal (2)
- Maxillae (2)
- Zygomatic (2)
- Mandible (1)
- Lacrimal (2)
- Palatine (2)
Bones of the Orbit

FRONTAL BONE
Suprornbral margin
Nasal Bone
Sphenoid Bone
Optic foramen
Superior orbital fissure
Palatine Bone
Zygomaticofacial foramen
Zygomatic Bone
Infraorbital foramen

Sutures

Frontal suture
Zygomatic arch
Occipital bone
Lamina papyracea
Maxillary sinus
Frontal bone
Lacrimal bone
Sphenoid bone
Temporal bone
Zygomatic bone
Vomer
Mandible

Coronal suture
Parietal bone
Temporal squama
Squamosal suture
Zygomatic process
Lacrimal bone
Lacrimal fossa
Nasal bone
Lacrimal bone
Lacrimal fossa
Sphenoid bone
Frontal bone
Zygomatic arch
Mandible
Zygomatic bone
Vomer
Mandible
Temporal bone
Zygomatic bone
Mandible
Parietal bone
Sphenoid bone
Occipital bone
Squamosal suture
Frontal bone
Zygomatic arch
Malar bone
Zygomatic bone
Vomer
Mandible

Sutures

Coronal suture
Parietal bone
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Lacrimal bone
Lacrimal fossa
Nasal bone
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Sphenoid bone
Frontal bone
Zygomatic arch
Mandible
Zygomatic bone
Vomer
Mandible
Temporal bone
Zygomatic bone
Mandible
Parietal bone
Sphenoid bone
Occipital bone
Squamosal suture
Frontal bone
Zygomatic arch
Malar bone
Zygomatic bone
Vomer
Mandible

Sutures
Ethmoid bone

- Lateral mass
- Ethmoidal "cello"
- Crista galli
- Perpendicular plate
- Superior nasal concha
- Middle nasal concha
- Perpendicular plate

Sphenoid bone

- Incisor teeth
- MAXILLA (palatine process)
- PALATINE BONE (horizontal plate)
- Middle nasal concha
- Sphenoidal processes
- Articular tubercle
- Styloid process
- External auditory meatus
- Stylo mastoid foramen
- Mastoid process
- Occipital condyle
- OCCIPITAL BONE
- Superior nuchal line
- Lambdoid suture
- External occipital protuberance

Sphenoid from Superior View

- Coronal suture
- Superior orbital fissure
- Foramen rotundum
- Foramen ovale
- Internal auditory meatus
- Hypoglossal foramen
- Foramen magnum
- OCCIPITAL BONE

Sphenoid in Anterior View

- Greater wings
- Lesser wings
- Superior orbital fissure
- Pterygoid processes

Body is a cubelike portion holding sphenoid sinuses
Greater and lesser wings
Pterygoid processes
Paranasal Sinuses

- Paired cavities in ethmoid, sphenoid, frontal and maxillary
- Lined with mucous membranes and open into nasal cavity
- Resonating chambers for voice, lighten the skull

Nasal Septum

- Divides nasal cavity into left and right sides
- Formed by vomer, perpendicular plate of ethmoid and septal cartilage
- Deviated septum does not line in the midline

Fontanels of the Skull at Birth.

- Dense connective tissue membrane-filled spaces (soft spots)
- Unossified at birth but close early in a child’s life.
- Fetal skull passes through the birth canal.
- Rapid growth of the brain during infancy
Hyoid Bone

- U-shaped single bone
- Articulates with no other bone of the body
- Suspended by ligament and muscle from skull
- Supports the tongue & provides attachment for tongue, neck and pharyngeal muscles

Vertebral Column

- Backbone or spine built of 26 vertebrae
- Five vertebral regions:
  - Cervical vertebrae (7) in the neck
  - Thoracic vertebrae (12) in the thorax
  - Lumbar vertebrae (5) in the low back region
  - Sacrum (5, fused)
  - Coccyx (4, fused)

Normal Curves of the Vertebral Column

- Primary curves:
  - Thoracic and sacral are formed during fetal development
- Secondary curves:
  - Cervical if formed when infant raises head at 4 months
  - Lumbar forms when infant sits up & begins to walk at 1 year

Typical Vertebrae

- Body
  - Weight bearing
- Vertebreal arch
  - Pedicles
  - Laminae
- Vertebreal foramen
- Seven processes
  - 2 transverse
  - 1 spinous
  - 4 articular
- Vertebreal notches
Intervertebral Discs

- Between adjacent vertebrae absorbs vertical shock
- Permit various movements of the vertebral column
- Fibrocartilagenous ring with a pulpy center

Intervertebral Foramen & Spinal Canal

- Spinal canal is all vertebral foramen together
- Intervertebral foramen are 2 vertebral notches together

Typical Cervical Vertebrae (C3-C7)

- Smaller bodies
- Larger spinal canal
- Transverse processes
  - shorter
  - foramen for vertebral artery
- Spinous processes of C2 to C6 often bifid
- 1st and 2nd

Atlas & Axis (C1-C2)

- Atlas -- ring of bone, superior facets for occipital condyles
  - Nodding movement at atlanto-occipital joint signifies "yes"
- Axis -- dens or odontoid process is body of atlas
**Thoracic Vertebrae (T1-T12)**
- Larger and stronger bodies
- Longer transverse & spinous processes
- Facets or demifacets on body for head of rib
- Facets on transverse processes (T1-T10) for tubercle of rib

**Lumbar Vertebrae**
- Strongest & largest
- Short thick spinous & transverse processes
- – back musculature

**Sacrum**
- Union of 5 vertebrae (S1 - S5) by age 30
  - Median sacral crest was spinous processes
  - Sacral ala is fused transverse processes
- Sacral canal ends at sacral hiatus
- Auricular surface & sacral tuberosity of SI joint

**Coccyx**
- Union of 4 vertebrae (Co1 - Co4) by age 30
  - Caudal or epidural anesthesia during delivery
  - Into sacral hiatus anesthetize sacral & coccygeal nerves
Thorax

- Bony cage flattened from front to back
- Sternum (breastbone)
- Ribs
  - 1-7 are true ribs (vertebrosternal)
  - 8-12 are false ribs (vertebrochondral)
  - 11-12 are floating
- Costal cartilages
- Bodies of the

Sternum

- Manubrium
  - 1st & 2nd ribs
  - clavicular notch
- Body
  - costal cartilages of 2-10 ribs
  - CPR position
- Xiphoid
  - ossifies by 40 abdominal mm.
- Sternal puncture
  - biopsy

A sternal puncture is used to aspirate red bone marrow for biopsy.
Skeletal System

**Ribs**
- Increase in length from ribs 1-7, thereafter decreasing
- Head and tubercle articulate with facets
- Body with costal groove containing nerve & blood vessels
- Fracture at site of greatest curvature.

**Rib Articulation**
- Tubercle articulates with transverse process
- Head articulates with vertebral bodies

**Appendicular Skeleton**
- There are 126 bones of the appendicular skeleton
- It includes bones of the pectoral (shoulder) girdles
- upper extremities
- pelvic (hip) girdle
- lower extremities

**Pectoral (Shoulder) Girdle**
- Attaches the bones of the upper extremities to the axial skeleton
- Composed of 4 bones (two clavicles and two scapulae)
  - The clavicle is the most frequently broken bone in the body; a fractured clavicle is common because this bone transmits forces from the upper extremity to the trunk
  - The scapulae articulate with other bones anteriorly, but are held in place posteriorly only by complex shoulder and back musculature
- Primary function is to provide an attachment point for the numerous muscles that allow the shoulder and elbow joints to move
  - because only the clavical attaches to the axial skeleton, the scapula can move freely across the thorax, allowing the arm to move with it
  - the socket of the shoulder joint is shallow and poorly reinforced, so it does not restrict movement of the numerous
**Skeletal System**

**Clavicle**

- Superior view
- Conoid tubercle
- Sternal end
- Acromial end
- Conoid tubercle

**Normal x-ray of clavicle**

**Fractured clavical**

**Normal anatomy**

**Dislocated shoulder**
Upper Extremity

- Each upper extremity contains 30 bones (60 total)
  - Arm (brachium)
  - Forearm
    - Ulna
    - Radius
  - Hand
    - Wrist
    - Palm
    - Fingers
The Forearm (Antebrachium)

- Region between the elbow and the wrist
- Contains ulna and the radius, which lie parallel to one another
  - when the hand is turned over so that the palm is facing downwards, the radius crosses over the ulna
  - the top of each bone connects to the humerus of the arm and the bottom of each connects to the bones of the hand
  - ulna on the little finger side
    - The ulna is longer than the radius and connected more firmly to the humerus
  - radius on the thumb side
    - The radius contributes more to the movement of the wrist and hand than the ulna
The Hand

- The hand consists of 27 bones divided into three parts
  - the wrist
  - palm
  - five fingers
Pelvic (Hip) girdle

- Consists of two hipbones (coxal bones or os coxae)
- Provides a strong and stable support for the lower extremities, on which the weight of the body is carried

Bony Pelvis
- Hip bones
- Sacrum
- Coccyx

Hip bones
- Ilium
- Ischium
- Pubis
Pelvic inlet & Pelvic outlet

male

female

Head
Neck
Greater trochanter
Condyles
Tibial tuberosity