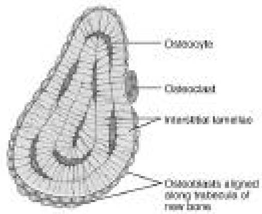
Chapter 6
The Skeletal System:Bone Tissue



- Dynamic and ever-changing throughout life
- Skeleton composed of many different tissues
  - cartilage, bone tissue, epithelium, nerve, blood forming tissue, adipose, and dense connective tissue

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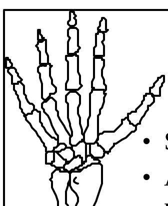

Functions of Bone

- Supporting & protecting soft tissues
- Attachment site for muscles making movement possible
- Storage of the minerals, calcium & phosphate -- mineral homeostasis
- Blood cell production occurs in red bone marrow (hemopoiesis)
- Energy storage in yellow bone marrow

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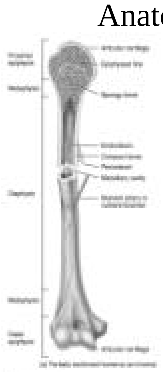
Anatomy of a Long Bone



- Diaphysis = shaft
- Epiphysis = one end of a long bone
- Metaphysis = growth plate region
- Articular cartilage over joint surfaces acts as friction & shock absorber
- Medullary cavity = marrow cavity
- Endosteum = lining of marrow cavity
- Periosteum = tough membrane covering bone but not the cartilage
  - fibrous layer = dense irregular CT
  - osteogenic layer = bone cells & blood vessels that nourish or help with repairs

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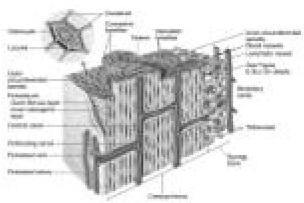
Histology of Bone

- A type of connective tissue as seen by widely spaced cells separated by matrix
- Matrix of 25% water, 25% collagen fibers & 50% crystalized mineral salts
- 4 types of cells in bone tissue



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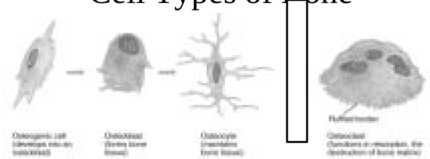
Cell Types of Bone



- Osteoprogenitor cells ---- undifferentiated cells
  - can divide to replace themselves & can become osteoblasts
  - found in inner layer of periosteum and endosteum
- Osteoblasts--form matrix & collagen fibers but can't divide
- Osteocytes ---mature cells that no longer secrete matrix
- Osteoclasts---- huge cells from fused monocytes (WBC)
  - function in bone resorption at surfaces such as endosteum

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Matrix of Bone

- Inorganic mineral salts provide bone's hardness
  - hydroxyapatite (calcium phosphate) & calcium carbonate
- Organic collagen fibers provide bone's flexibility
  - their tensile strength resists being stretched or torn
  - remove minerals with acid & rubbery structure results
- Mineralization (calcification) is hardening of tissue when mineral crystals deposit around collagen fibers
- Bone is not completely solid since it has small spaces for vessels and red bone marrow
  - spongy bone has many such spaces
  - compact bone has very few

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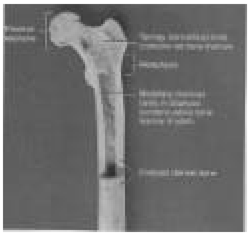
Compact or Dense Bone



- Looks like solid hard layer of bone
- Makes up the shaft of long bones and the external layer of all bones
- Resists stresses produced by weight and movement

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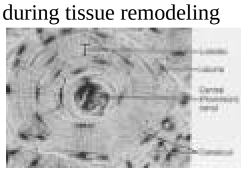
Histology of Compact Bone

- Osteon is concentric rings (lamellae) of calcified matrix surrounding a vertically oriented blood vessel
- Osteocytes found in spaces called lacunae
- Osteocytes communicate through canaliculi filled with extracellular fluid that connect one cell to the next cell
- Interstitial lamellae represent older osteons that have been partially removed during tissue remodeling



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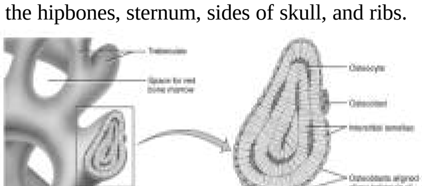
The Trabeculae of Spongy Bone

- Latticework of thin plates of bone called trabeculae oriented along lines of stress
- Spaces in between these struts are filled with red marrow where blood cells develop
- Found in ends of long bones and inside flat bones such as the hipbones, sternum, sides of skull, and ribs.



No true Osteons.

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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

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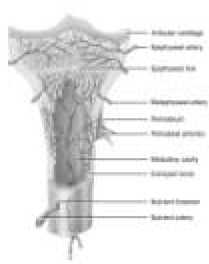
Blood and Nerve Supply of Bone

- Periosteal arteries
  - supply periosteum
- Nutrient arteries
  - enter through nutrient foramen
  - supplies compact bone of diaphysis & red marrow
- Metaphyseal & epiphyseal aa.
  - supply red marrow & bone tissue of epiphyses



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Bone Formation or Ossification

- All embryonic connective tissue begins as mesenchyme.
- Intramembranous bone formation = formation of bone directly from mesenchymal cells.
- Endochondral ossification = formation of bone within hyaline cartilage.

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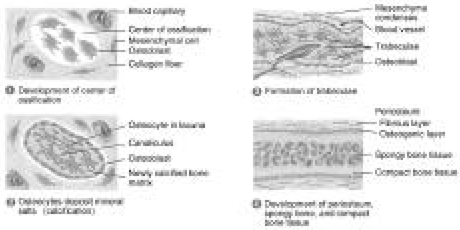
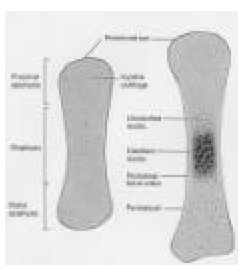
Intramembranous Bone Formation



- Mesenchymal cells become osteoprogenitor cells then osteoblasts.
- Osteoblasts surround themselves with matrix to become osteocytes.
- Matrix calcifies into trabeculae with spaces holding red bone marrow.
- Mesenchyme condenses as periosteum at the bone surface.
- Superficial layers of spongy bone are replaced with compact bone.

Endochondral Bone Formation (1)

- Development of Cartilage model
  - Mesenchymal cells form a cartilage model of the bone during development
- Growth of Cartilage model
  - in length by chondrocyte cell division and matrix formation (interstitial growth)
  - in width by formation of new matrix on the periphery by new chondroblasts from the perichondrium (appositional growth)
  - cells in midregion burst and change pH triggering calcification and chondrocyte death



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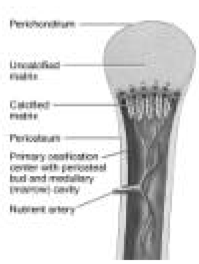
Endochondral Bone Formation (2)

- Development of Primary Ossification Center
  - perichondrium lays down periosteal bone collar
  - nutrient artery penetrates center of cartilage model
  - periosteal bud brings osteoblasts and osteoclasts to center of cartilage model
  - osteoblasts deposit bone matrix over calcified cartilage forming spongy bone trabeculae
  - osteoclasts form medullary cavity



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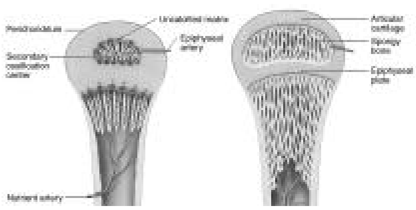
Endochondral Bone Formation (3)



- Development of Secondary Ossification Center
  - blood vessels enter the epiphyses around time of birth
  - spongy bone is formed but no medullary cavity
- Formation of Articular Cartilage
  - cartilage on ends of bone remains as articular cartilage.

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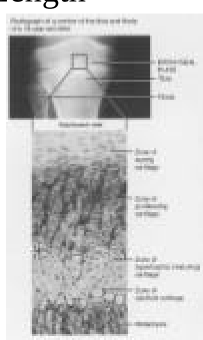
Bone Growth in Length

- 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



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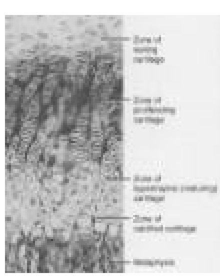
Zones of Growth in Epiphyseal Plate

- Zone of resting cartilage
  - anchors growth plate to bone
- Zone of proliferating cartilage
  - rapid cell division (stacked coins)
- Zone of hypertrophic cartilage
  - cells enlarged & remain in columns
- Zone of calcified cartilage
  - thin zone, cells mostly dead since matrix calcified
  - osteoclasts removing matrix
  - osteoblasts & capillaries move in to create bone over calcified cartilage



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Bone 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.

Factors Affecting Bone Growth

- Nutrition
  - adequate levels of minerals and vitamins
    - calcium and phosphorus for bone growth
    - vitamin C for collagen formation
    - vitamins K and B12 for protein synthesis
- Sufficient levels of specific hormones
  - during childhood need insulinlike growth factor
    - promotes cell division at epiphyseal plate
    - need hGH (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

6-20

Hormonal Abnormalities

- Oversecretion of hGH during childhood produces giantism
- Undersecretion of hGH or thyroid hormone during childhood produces short stature
- Both men or women that lack estrogen receptors on cells grow taller than normal
  - estrogen responsible for closure of growth plate

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Bone Remodeling

- Ongoing since osteoclasts carve out small tunnels and osteoblasts rebuild osteons.
  - osteoclasts form leak-proof seal around cell edges
  - secrete enzymes and acids beneath themselves
  - release calcium and phosphorus into interstitial fluid
  - osteoblasts take over bone rebuilding
- Continual redistribution of bone matrix along lines of mechanical stress
  - distal femur is fully remodeled every 4 months

6-22

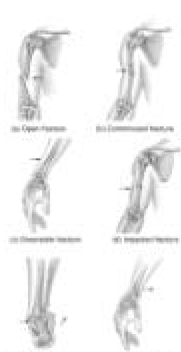
Fracture & Repair of Bone

- Fracture is break in a bone
- Healing is faster in bone than in cartilage due to lack of blood vessels in cartilage
- Healing of bone is still slow process due to vessel damage
- Clinical treatment
  - closed reduction = restore pieces to normal position by manipulation
  - open reduction = surgery

6-23

Fractures

- Named for shape or position of fracture line
- Common types of fracture
  - closed -- no break in skin
  - open fracture --skin broken
  - comminuted -- broken ends of bones are fragmented
  - greenstick -- partial fracture
  - impacted -- one side of fracture driven into the interior of other side
  - Pott's -- distal fibular fracture
  - Colles's -- distal radial fracture
  - stress fracture -- microscopic fissures from repeated strenuous activities



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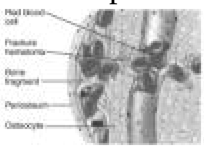
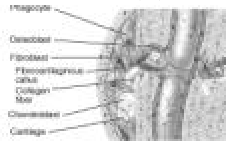
Repair of a Fracture (1)

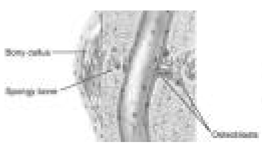


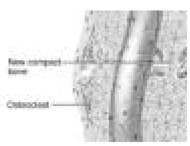


- Formation of fracture hematoma
  - damaged blood vessels produce clot in 6-8 hours, bone cells die
  - inflammation brings in phagocytic cells for clean-up duty
  - new capillaries grow into damaged area
- Formation of fibrocartilagenous callus formation
  - fibroblasts invade the procallus & lay down collagen fibers
  - chondroblasts produce fibrocartilage to span the broken ends of the bone

6-25

Repair of a Fracture (2)





- Formation of bony callus
  - osteoblasts secrete spongy bone that joins 2 broken ends of bone
  - lasts 3-4 months
- Bone remodeling
  - compact bone replaces the spongy in the bony callus
  - surface is remodeled back to normal shape

6-26

Calcium Homeostasis & Bone Tissue

- Skeleton is reservoir of Calcium & Phosphate
- Calcium ions involved with many body systems
  - nerve & muscle cell function
  - blood clotting
  - enzyme function in many biochemical reactions
- Small changes in blood levels of Ca+2 can be deadly (plasma level maintained 9-11mg/100mL)
  - cardiac arrest if too high
  - respiratory arrest if too low

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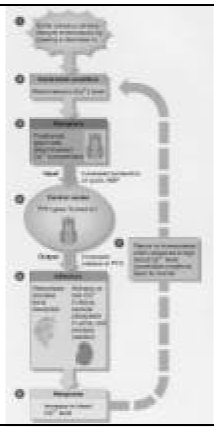

Hormonal Influences

- Parathyroid hormone (PTH) is secreted if Ca+2 levels falls
  - PTH gene is turned on & more PTH is secreted from gland
  - osteoclast activity increased, kidney retains Ca+2 and produces calcitriol
- Calcitonin hormone is secreted from parafollicular cells in thyroid if Ca+2 blood levels get too high
  - inhibits osteoclast activity
  - increases bone formation by osteoblasts

6-28

Exercise & Bone Tissue

- Pull on bone by skeletal muscle and gravity is mechanical stress .
- Stress increases deposition of mineral salts & production of collagen (calcitonin prevents bone loss)
- Lack of mechanical stress results in bone loss
  - reduced activity while in a cast
  - astronauts in weightlessness
  - bedridden person
- Weight-bearing exercises build bone mass (walking or weight-lifting)

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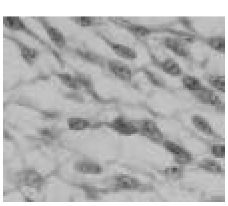
Development of Bone Tissue



Mesenchymal Cells

- Both types of bone formation begin with mesenchymal cells
- Mesenchymal cells transform into chondroblasts which form cartilage

OR

- Mesenchymal cells become osteoblasts which form bone

6-30

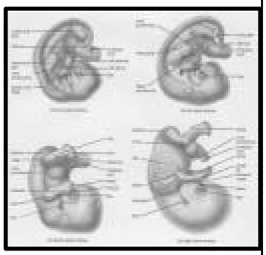
Developmental Anatomy

5th Week =limb bud appears as mesoderm covered with ectoderm

6th Week = constriction produces hand or foot plate and skeleton now totally cartilaginous

7th Week = endochondral ossification begins

8th Week = upper & lower limbs appropriately named



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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

6-32

Osteoporosis

- Decreased bone mass resulting in porous bones
- Those at risk
  - white, thin menopausal, smoking, drinking female with family history
  - athletes who are not menstruating due to decreased body fat & decreased estrogen levels
  - people allergic to milk or with eating disorders whose intake of calcium is too low
- Prevention or decrease in severity
  - adequate diet, weight-bearing exercise, & estrogen replacement therapy (for menopausal women)
  - behavior when young may be most important factor

6-33

Disorders of Bone Ossification

- Rickets
  - calcium salts are not deposited properly
  - bones of growing children are soft
  - bowed legs, skull, rib cage, and pelvic deformities result
- Osteomalacia
  - new adult bone produced during remodeling fails to ossify
  - hip fractures are common

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