Chapter 6: The Skeletal System: Bone Tissue

Chapter Objectives

FUNCTIONS OF THE SKELETAL SYSTEM

1. Discuss the functions of support, protection, assistance in movement, mineral homeostasis, blood cell production, and triglyceride storage.

STRUCTURE OF BONE

2. List the types of bones.
3. List and describe the parts of the long bone.

HISTOLOGY OF BONE TISSUE

4. Describe the four types of cells in bone tissue and their function.
5. Describe the chemical components of bone.
6. Describe the histological features and their functions found in compact bone tissue.
7. Contrast and compare the structure and composition of spongy bone versus compact bone.

BONE FORMATION

8. Compare and contrast the two types of bone formation, noting the location where each kind of ossification occurs.
9. Describe the steps involved in intramembranous ossification.
10. Describe the steps involved in endochondral ossification.
11. Describe the zones of the epiphyseal plate and the role of the epiphyseal plate in growth in the length of bones. Know what structure of a long grows in length.
12. Describe the process of growth in thickness. List and describe the function of the cells responsible for this process.
13. Discuss the roles of osteoclasts and osteoblasts in bone remodeling processes.
14. Discuss the role of minerals, vitamins, and hormones in bone growth and remodeling.
15. Describe osteoporosis, rickets, osteomalacia, osteomyelitis, osteogenic sarcoma, and malignant myeloma. Explain the cause of each disorder.
16. Define a fracture and describe several common kinds of fractures.
17. List and describe the steps involved in fracture repair.

Chapter Lecture Notes

Functions of Bone

Attachment of skeletal muscles via tendons; when muscles contract, movement results
Supports Soft Tissue

Protection of vital organs such as central nervous system housed in cranial cavity and vertebral column

Reservoir of minerals such as calcium and phosphorus

Hemopoiesis - manufacture of blood cells in red bone marrow

in adults; proximal epiphysis of humerus and femur; ribs, sternum, clavicle, os coxae, vertebrae, skull

Storage of triglycerides

Types of Bone

Long bones – bones longer than they are wide (Fig 7.2)

femur, humerus, phalanges, etc.

Short bones – cube shaped

wrist and ankle

Flat bones – thin, flattened and a bit curved

sternum, scapula, ribs and skull

Irregular bones

vertebrae and hip bones

Sesamoid bones – develop in tendons under stress

patella

Structure of Long Bone

Diaphysis - shaft - hollow in middle and contains mostly yellow marrow (Fig 6.1)

Medullary (marrow) cavity - runs length of diaphysis and usually contains yellow marrow

(storage of triglycerides in adults)

Epiphysis - ends of bone - red marrow in proximal epiphysis of humerus and femur; yellow marrow in other epiphysis

Metaphysis – between diaphysis and epiphysis
Epiphyseal plate – a layer of hyaline cartilage that allows the diaphysis to grow in length –
  growth plate

Epiphyseal line – bony structure that replaces epiphyseal plate when bone stops growing

Periosteum - outside covering of bone except at joint surface present as 2 layers;
  inner layer – cell layer
    single layer that contains osteoprogenitor cells and osteoblasts
  outer layer – fibrous layer
    made of dense irregular CT
    vascular layer because it contains blood vessels, lymph vessels, nerves that pass into bone
    serves as points of attachment of tendons and ligaments

Endosteum - usually a single layer of cells that lines medullary (marrow) cavity, central and
  Volkmann's canals and covers trabeculae of spongy bone
  contains osteoprogenitor cells, osteoblasts and osteoclasts

Articular cartilage - covers the articular surface of each epiphysis
  hyaline cartilage
  prevents friction and damage at joints

Bone Cells

Osteoprogenitor (osteogenic cells) (Fig 6.2)
  derived from mesenchyme
  capable of mitosis and develops into osteoblasts
  located in inner periosteum and endosteum in Volkmann's and central canals

Osteoblasts (not capable of mitosis)
  produce collagen and bone tissue
  located in inner periosteum and endosteum in Volkmann's and central canals

Osteocytes (maintain bone)
  Located in lacuna between lamellae
Osteoclasts (bone digesting cells)

develop from monocytes

release collagenase (digest collagen) and acids (dissolve Ca\(^{2+}\) salts) that digest bone

located in the endostenum

Microscopic Structure of Bone

Compact Bone (Fig 6.3)

By weight, bone has 25% water, 25% collagen fibers and 50% calcium phosphate

Collagen fibers produced by osteoblasts (Ca\(^{2+}\) salts deposit along collagen)

Osteoblasts become trapped in lacuna and then are known as osteocytes

Cytoplasmic extensions from osteocytes are located in canaliculi

Nutrients reach osteocytes via canaliculi and cytoplasmic extensions from central canal

Matrix arranged in concentric rings around central canal called lamella/e

Osteon (Haversian system) - central canal and surrounding lamella

Spongy Bone (Fig 6.3)

Has latticework of thin plates of bone called trabeculae (beams of bone)

Within trabeculae are lacunae with osteocytes that are connected by canaliculi

Osteocytes are nourished directly from blood circulating between trabeculae

Spaces between trabeculae may contain red bone marrow capable of hemopoiesis

Bone Formation - Ossification

Embryonic skeleton composed of fibrous membrane and hyaline cartilage in shape of bones

Ossification begins 6th week of embryonic life

Bone cells develop from mesenchymal cells

when mesenchyme migrate into area that form bone, they either form chondroblasts or osteoblasts;

if no capillaries; mesenchyme form chondroblasts

if have capillaries; mesenchyme form osteoprogenitor cells
Ossification replaces preexisting CT with bone

**Intramembranous formation (Fig 6.5)**

occurs in flat bones of skull, part of clavicle

begins at 6 weeks of embryonic life

mesenchyme cells in fibrous membrane differentiate into osteoblasts that secrete collagen

osteoblasts secrete an enzyme that encourages deposit of Ca\(^{2+}\) salts along collagen

trabeculae form and fuse with other trabeculae

osteoblasts become osteocytes and are trapped in lacunae

spaces between trabeculae fill with red marrow

outside covering becomes 2 layered periosteum

surface layers eventually reconstructed into compact bone because osteoblasts on surface

reconstruct bone (much of newly formed bone will be destroyed and reformed)

at birth, those areas of membrane that have not yet ossified are the fontanels

**Endochondral formation (Fig 6.6)**

gives rise to all other bones

begins at 8 weeks of embryonic life

hyaline cartilage model, which is covered with perichondrium, is first formed and is replaced by bone

**Primary ossification center**

blood vessels penetrate the perichondrium in the center of the diaphysis and stimulate osteoprogenitor cells of internal layer of perichondrium to enlarge and become osteoblasts (once perichondrium starts to produce bone, it is called the periosteum)

the osteoblasts secrete an enzyme which encourages Ca\(^{2+}\) salts to deposit in the matrix

osteoblasts then form a thin layer of calcified bone tissue under the periosteum, the bony collar
the bony collar and the newly calcified matrix restrict nutrient flow to the existing chondrocytes, the cartilage cells hypertrophy because nutrients cannot diffuse to the chondrocytes (lack canaliculi) and they die, causing cavities to form in the cavities osteoblasts form new spongy bone tissue osteoclasts digest out more cavity, forming marrow cavity of diaphysis

Secondary ossification center - more blood vessels enter the epiphysis, bringing with it osteoprogenitor cells that develop into osteoblasts which produce spongy bone secondary centers do not begin until after birth after the secondary centers have formed, bone tissue completely replaces cartilage except in two regions:
articular cartilage epiphyseal plate

Bone Growth

Growth in length (Fig 6.7)
Occurs at epiphyseal plate
Adds length to diaphysis pushing epiphyses away from each other epiphysial plate has 4 distinct zones of cells
zone of resting (quiescent) cartilage - epiphyseal side (no mitosis) zone of proliferating cartilage – mitosis zone of hypertrophic cartilage - cartilage cells enlarging zone of calcified cartilage - dying cartilage cells on diaphyseal side Epiphyseal cartilage stops dividing and is replaced by bone at puberty with surge of hormones what remains is the epiphyseal line

Growth in diameter (Fig 6.8)
New osteons are constructed on the outside of a bone
osteoblasts from the periosteum add new bone tissue, enclosing a blood vessel running through the periosteum

once the blood vessel is enclosed, the periosteum becomes the endosteum inside the newly formed central canal

the osteoblasts in the endosteum continue to make more bone tissue in concentric rings, lamellae, resulting in a new osteon

while new bone is being made on the outside of the bone, osteoclasts in medullary endosteum destroy bone lining the marrow cavity

Reconstruction/remodeling is replacement of old bone tissue by new bone tissue and is part of bone maintenance

Old bone and worn out bone is constantly reworked

Distal end of femur is replaced every 4 months

Remodeling of bone is necessary to replace the initial spongy bone of newly made bone with compact bone on the outside of a bone

Why Reconstruction/remodeling

Old bone weakened by degeneration of organic matrix must be replaced

Constant exchange of Ca^{2+} (bones store 99% of Ca^{2+})

Bone adjusts and thickens under mechanical stress

fracture repair is a form of bone remodeling that involves reshaping bones by putting them under stress in a cast

bones of athletes are heavier

movement of teeth in orthodontics involves reshaping of alveoli by stress applied with braces

Hormones and vitamins that regulate growth and remodeling of bone (Table 6.2)

Growth hormone (pituitary gland) and thyroxin (thyroid) - normal bone growth in young people
Parathyroid hormone - increases osteoclast activity

- increases $\text{Ca}^{2+}$ in blood (Fig 6.10)

Calcitonin- (thyroid) increases osteoblast activity,

- accelerate deposit of $\text{Ca}^{2+}$ into bone

- blood $\text{Ca}^{2+}$ levels decrease

Vitamin D (calcitriol) - sun converts cholesterol derivative into Vitamin D in skin

- Vitamin D is needed to absorb $\text{Ca}^{2+}$ from intestine (Vitamin D aids in synthesis of a carrier protein molecule that is needed to transport $\text{Ca}^{2+}$)

Rickets - decrease in Vitamin D in children; cartilage cells grow; ossification occurs but little calcification; bones bow under weight because bones are soft (collagen is flexible)

Osteomalacia - decrease of Vitamin D in adults

Sex hormones - osteoblasts have receptors for sex hormones

- osteoporosis – porous bones (Fig 6.11)

Caused by decrease of sex hormones with advancing age

- more common in females because of menopause when estrogen production essentially halts

- adequate diet which may include $\text{Ca}^{2+}$, exercise, and medication, including low dose estrogen replacement may be indicated for prevention of osteoporosis in females

Vitamin C - promotes synthesis of collagen

Bone Disorders

Osteomyelitis – bacterial infection in bone (often Staph aureus)

- bacteria reaches bone by blood, fractures, sinus infection, tooth abscess

- antibiotics are effective
Osteogenic sarcoma (osteosarcoma) - malignant cancer of osteoblasts predominant in young people 10-25 years

frequently metastasizes, so amputation frequently done

Malignant myelomas - most common form of bone cancer

myeloid = marrow

can either start in bone or start after metastasis from breast, prostate cancers

interferes with hemopoiesis

Fractures - any break in bone (Table 6.1)

simple/closed - broken ends do not penetrate through skin (completely internal)

    Pott’s or Colles’

compound/open - broken ends protrude through skin

comminuted - bone shattered into many pieces

compression/impacted – bone is crushed or driven into another bone

greenstick - one side breaks, other side bends; mainly in children

depressed - broken bone portion is pressed inward

spiral – ragged break occurs when excessive twisting forces are applied to bone

epiphyseal – epiphysis separates from the diaphysis along the epiphyseal plate

Fracture repair – coordinated effort of osteoblasts and osteoclasts (Fig 6.9)

hematoma - from bleeding of blood vessel into osteons, periosteum, marrow cavity

fibrocartilaginous callus - forms a bridge of fibrocartilage between separated area

bony callus - growth of new bone tissue – replaces fibrocartilage

bone remodels to be like other bone