The Skeletal System: Bone Tissue

6.4-6.9

6.5 Bone Formation

- Objectives
  - Describe the steps of intramembranous and endochondral ossification
  - Explain how bone grows in length and thickness
  - Describe the process involved in bone remodeling

- Ossification or osteogenesis is the process of forming new bone
- Bone formation occurs in four situations:
  - Formation of bone in an embryo and fetus
  - Growth of bones until adulthood
  - Remodeling of bone
  - Repair of fractures

Initial Bone Formation in an Embryo & Fetus

- Osteogenesis occurs by two different methods, beginning about the 6th week of embryonic development
- Intramembranous ossification
  - Produces spongy bone
  - This bone may subsequently be remodeled to form compact bone
- Endochondral ossification
  - Process where cartilage is replaced by bone
  - Forms both compact and spongy bone

- Intramembranous ossification is the simpler of the two methods
  - It is used in forming the flat bones of the skull, mandible, and clavicle
  - Bone forms from mesenchymal cells that develop within a membrane, without going through a cartilage stage
  - Arranged in sheetlike layers that resemble membranes
  - Many ossification centers

- Endochondral ossification is the method used in the formation of most bones, especially long bones
  - Bone formation within hyaline cartilage that develops from mesenchyme
  - There are one primary and two secondary centers of growth
    - The primary ossification center of a long bone is in the diaphysis
    - Cartilage degenerates, leaving cavities that merge to form the medullary cavity
    - Osteoblasts lay down bone
    - Ossification occurs in the epiphyses, where bone replaces cartilage, except for the epiphyseal (growth) plate

Bone Growth During Infancy, Childhood, & Adolescence

- The epiphyseal plate consists of four zones
  - Resting cartilage
  - Proliferating cartilage
  - Hypertrophic cartilage
  - Calcified cartilage
- Because of the cell division in the epiphyseal plate, the diaphysis of a bone increases in length
- Bone grows in thickness or diameter due to the addition of new bone tissue by periosteal osteoblasts around the outer surface of the bone
  - Appositional growth
• Ossification contributing to bone length is usually complete by 18-21 years of age.

• Bones can still continue to thicken and are capable of repair even after the epiphyseal growth plates have closed.

• Human growth hormone is one of the body’s many anabolic hormones.
  – Its secretion will stimulate bone growth, muscle growth, loss of fat, and increased glucose output in the liver.
  – The use of growth hormone has been increasing in popularity among athletes due to the numerous “benefits” associated with its use; side effects are often not thought of when young athletes use these drugs.

• Remodeling of Bone
  – Bone remodeling is an ongoing process in which osteoclasts carve out small tunnels in old bone tissue and then osteoblasts rebuild it.
  – A balance must exist between the actions of osteoclasts and osteoblasts.
  – If too much new tissue is formed, the bones become abnormally thick and heavy (acromegaly).
  – Excessive loss of calcium weakens the bones, as occurs in osteoporosis.
  – They may also become too “soft”, as seen in the bone diseases rickets and osteomalacia.
  – In bone resorption, osteoclasts release enzymes and acids that degrade collagen fibers and dissolve mineral salts.

Factors Affecting Bone Growth & Remodeling

• Minerals are an essential component.
  – Large amounts of calcium and phosphorus and smaller amounts of magnesium, fluoride, and manganese are required for bone growth and remodeling.

• Vitamins are also necessary for normal bone metabolism:
  – Vitamin A stimulates activity of osteoblasts.
  – Vitamin C is needed for synthesis of collagen.
  – Vitamin D is essential to healthy bones because it promotes the absorption of calcium from foods in the gastrointestinal tract into the blood.
  – Vitamins K and B₁₂ are needed for synthesis of bone proteins.

• Hormones are key contributors to normal bone metabolism:
  – During childhood, the hormones most important to bone growth are human growth hormone (hGH) and growth factors called IGFs (produced by the liver).
  – Both stimulate osteoblasts, promote cell division at the epiphyseal plate, and enhance protein synthesis.
  – Thyroid hormones and insulin also promote bone growth by stimulating osteoblasts and protein synthesis.

• The sex hormones (estrogen and testosterone) cause a dramatic effect on bone growth, such as the sudden “growth spurt” that occurs during the teenage years.
  – The sex hormones also promote widening of the pelvis in the female skeleton.
  – They are also responsible for closing the epiphyseal plates at the end of puberty.
  – They also slow resorption of old bone and promote new bone deposition.

6.6 Fracture & Repair of Bone

• Objectives
  – Describe several common types of fractures.
  – Describe the sequence of events involved in fracture repair.

• Remodeling of fractures can be confusing because of the many different criteria that are used.
  – Some schemes describe the anatomical appearance of the fracture:
    • Partial
    • Complete (fx is all the way through the bone)
    • Closed (simple)
    • Open (fx punctures the skin)
    • “Green stick” (a small linear break in the bone cortex)
    • Impacted
    • Comminuted
    • Spiral
    • Transverse
    • Displaced.
• Other fractures are classified by the disease or mechanism which produced the fracture
  • Pathological fracture
    • Usually from a cancerous process or severe chronic disease
  • Compression fracture
  • Produced by extreme forces such as in trauma
  • Stress fracture
  • Produced from repeated strenuous activities such as running

• Still other fractures describe a common pattern of injury, often involving more than one bone, and usually denoted by an eponym (someone’s name):
  • Colles’ fracture of the distal radius
  • Pott’s fracture of the distal fibula

• Once a bone is fractured, repair proceeds in a predictable pattern
  • The first step, which occurs 6-8 hours after injury, is the formation of a fracture hematoma as a result of blood vessels breaking in the periosteum and in osteons

The second and third steps involve the formation of a callus (takes a few weeks, to as many as six months)
  • Phagocytes remove cellular debris and fibroblasts deposit collagen to form a fibro-cartilaginous callus
  • Which is followed by osteoblasts forming a bony callus of spongy bone

The final step takes several months and is called remodeling
  • Spongy bone is replaced by compact bone
  • The fracture line disappears, but evidence of the break remains

6.7 Bone’s Role in Calcium Homeostasis
• Objectives
  • Describe the importance of calcium in the body
  • Explain how blood calcium level is regulated
Bone is the major reservoir for calcium in the body. Day to day control of calcium regulation mainly involves:

- Parathyroid hormone secreted by the parathyroid glands stimulates osteoclastic activity and raises serum calcium level
- Calcitonin (thyrocalcitonin), and to a lesser extent hGH and the sex hormones, stimulate osteoblastic activity and lower serum calcium level
- Vitamin D is needed for absorption of the \( \text{Ca}^{2+} \) and \( \text{PO}_4^- \) ions from the small intestine, and reabsorption of those same ions in the kidneys
- The role of regulating serum \( \text{Ca}^{2+} \) levels and mineralizing bone is under hormonal control, and is carefully balanced

6.8 Exercise & Bone Tissue

- Objectives
  - Describe how exercise and mechanical stress affect bone tissue

Under mechanical stress, bone tissue becomes stronger through deposition of mineral salts and production of collagen fibers by osteoblasts.

- Unstressed bones, on the other hand, become weaker because of demineralization and collagen fiber reduction.
- Astronauts in space suffer rapid loss of bone density.
- The main mechanical stresses on bone are those that result from the pull of skeletal muscles and the pull of gravity (weight-bearing activities).

6.9 Aging & Bone Tissue

- Objectives
  - Describe the effects of aging on bone tissue

A decrease in bone mass occurs as the level of sex hormones diminishes during middle age (especially in women after menopause).
- Bone resorption by osteoclasts outpaces bone deposition by osteoblast.
- Since female bones are generally smaller and less massive than males to begin with, old age has a greater adverse effect in females.

There are two principal effects of aging on bone tissue:
- Demineralization and loss of bone mass:
  - The loss of calcium from bones, due to reduced osteoblast activity, is one of the symptoms in osteoporosis.
  - Britteness:
    - Collagen fibers give bone its tensile strength, and protein synthesis decreases with age.
    - The loss of tensile strength causes the bones to become very brittle and susceptible to fracture.

Osteoporosis is a condition where bone reabsorption outpaces bone deposition:
- Often due to depletion of calcium from the body or inadequate intake.