The Skeletal System

Development & Remodeling
Bone Formation & Maintenance

- Ossification (osteogenesis)
  - Stages
    - Bone formation
      - Begins in the 2nd month of development
    - Postnatal bone growth
      - Until early adulthood
    - Bone remodeling and repair
      - Lifelong
Types of Ossification

1. Endochondral ossification
   • Bone forms by replacing hyaline cartilage
   • Forms most of the skeleton
2. Intramembranous ossification
   • Bone develops from fibrous membrane
   • Forms flat bones
Endochondral Ossification

- Uses hyaline cartilage models
  - Requires breakdown of hyaline cartilage prior to ossification
Bone collar forms around hyaline cartilage model.

Cartilage in the center of the diaphysis calcifies and then develops cavities.

The periosteal bud invades the internal cavities and spongy bone begins to form.

The diaphysis elongates and a medullary cavity forms as ossification continues. Secondary ossification centers appear in the epiphyses in preparation for stage 5.

The epiphyses ossify. When completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.

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**Figure 6.9**

- Bone collar forms around hyaline cartilage model.
- Cartilage in the center of the diaphysis calcifies and then develops cavities.
- The periosteal bud invades the internal cavities and spongy bone begins to form.
- The diaphysis elongates and a medullary cavity forms as ossification continues. Secondary ossification centers appear in the epiphyses in preparation for stage 5.
- The epiphyses ossify. When completed, hyaline cartilage remains only in the epiphyseal plates and articular cartilages.
Epiphyseal growth plates continue to produce cartilaginous elongation as long as bones are increasing in length.

1. **Proliferation zone**
   - Cartilage cells undergo mitosis.

2. **Hypertrophic zone**
   - Older cartilage cells enlarge.

3. **Calcification zone**
   - Matrix becomes calcified; cartilage cells die; matrix begins deteriorating.

4. **Ossification zone**
   - New bone formation is occurring.

Calcified cartilage spicule
Osteoblast depositing bone matrix
Osseous tissue (bone) covering cartilage spicules
Intramembranous Ossification

- Forms flat bones
  - Skull roof, lower jaw, clavicles
- Uses a fibrous membrane model formed from mesenchymal cells
Ossification centers appear in the fibrous connective tissue membrane.

- Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center.
Bone matrix (osteoid) is secreted within the fibrous membrane and calcifies.

- Osteoblasts begin to secrete osteoid, which is calcified within a few days.
- Trapped osteoblasts become osteocytes.
Bone Maintenance

- Bone is dynamic throughout human lifespan
- Remodeling has several functions
  - Replacement and repair
  - Release of calcium
  - Response to stress (modification of density)
Bone Remodeling

- **Deposit**
  - Where bone is injured or added strength is required
  - Osteoblasts

- **Resorption**
  - Releases minerals from bone
  - Osteoclasts
Control of Remodeling

- Hormones
  - Growth Hormone (GH)
  - Calcitonin
  - Parathyroid Hormone (PTH)
  - Sex hormones
Hormonal Control of Blood $\text{Ca}^{2+}$

$\downarrow$ Blood $\text{Ca}^{2+}$ levels

$\downarrow$

Parathyroid glands release PTH

$\downarrow$

PTH stimulates osteoclasts to degrade bone matrix and release $\text{Ca}^{2+}$

$\downarrow$

$\uparrow$ Blood $\text{Ca}^{2+}$ levels
Osteoclasts degrade bone matrix and release Ca\textsuperscript{2+} into blood.

Parathyroid glands release parathyroid hormone (PTH).

Calcium homeostasis of blood: 9–11 mg/100 ml

Stimulus: Falling blood Ca\textsuperscript{2+} levels

IMBALANCE

BALANCE
Bone Maintenance

- Bone deposition
  - Occurs where bone is injured or added strength is needed
- Development requires proper nutrition
  - Vitamins C, D, and A
  - Calcium and phosphorus