6

Bones and Bone Structure

Lecture Presentation by Lori Garrett

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Section 1: Introduction to the Structure and Growth of Bones

Learning Outcomes

6.1 Describe the two main divisions of the skeleton, and list the major functions of the skeletal system.

6.2 Classify bones according to their shapes, identify the major types of bone markings, and explain the functional significance of bone markings.

6.3 Identify the parts of a typical long bone, and describe its internal structures.

6.4 Identify the types of cells in bone, and list their major functions.
Section 1: Introduction to the Structure and Growth of Bones

Learning Outcomes (continued)

6.5 Compare the structures and functions of compact bone and spongy bone.

6.6 Describe the process of appositional bone growth.

6.7 Describe the process of endochondral ossification.

6.8 Describe the process of intramembranous ossification.

6.9 Clinical Module: Discuss various abnormalities of bone formation and growth.
Module 6.1: The skeletal system is made up of the axial and appendicular divisions

Bones (~206 total)

1. **Axial skeleton (80 bones)**
   - Bones of skull, thorax, and vertebral column
   - Form longitudinal axis of body

2. **Appendicular skeleton (126 bones)**
   - Bones of the limbs and girdles that attach them to the axial skeleton
   - Associated cartilages
   - Ligaments and other connective tissues
Functions of the skeletal system

Functions of the Skeletal System

- Support
- Store minerals and lipids
- Produce blood cells
- Protection
- Leverage
Module 6.1: Review

A. Describe the axial and appendicular divisions of the skeleton.

B. Identify the functions of the skeletal system.

*Learning Outcome:* Describe the two main divisions of the skeleton, and list the major functions of the skeletal system.
Module 6.2: Bones are classified according to shape and structure and have varied bone markings

Six categories of bone based on shape

1. Flat bones
2. Sutural bones
3. Long bones
4. Irregular bones
5. Sesamoid bones
6. Short bones
Module 6.2: Bone classification and surface markings

1. **Flat bones**
   - Thin, roughly parallel surfaces
   - *Examples*: cranial bones, sternum, ribs, scapulae
   - Protect underlying soft tissues
   - Provide surface area for skeletal muscle attachment

2. **Sutural bones (Wormian bones)**
   - Irregular bones formed between cranial bones
   - Number, size, and shape vary
Module 6.2: Bone classification and surface markings

3. **Long bones**
   - Relatively long and slender
   - *Examples*: various bones of the limbs

4. **Irregular bones**
   - Complex shapes with short, flat, notched, or ridged surfaces
   - *Examples*: vertebrae, bones of pelvis, facial bones
Module 6.2: Bone classification and surface markings

5. **Sesamoid bones**
   - Small, flat, and somewhat shaped like sesame seed
   - Develop inside tendons of knee, hands, and feet
   - Individual variation in location and number

6. **Short bones**
   - Small and boxy
   - *Examples*: bones of the wrist (carpals) and ankles (tarsals)
Bone classifications

- **Sutural Bones**
  - Sutural bone
  - Sutures

- **Flat Bones**
  - Parietal bone

- **Irregular Bones**
  - Vertebra

- **Short Bones**
  - Carpal bones

- **Long Bones**
  - Humerus

- **Sesamoid Bones**
  - Patella
Module 6.2: Bone classification and markings

Bone markings

- Also known as surface features
- Related to particular functions
  - Elevations/projections
    - Muscle, tendon, and ligament attachment
    - At joints where adjacent bones articulate
  - Depressions/grooves/tunnels
    - Sites for blood vessels or nerves to lie alongside or penetrate bone
Module 6.2: Bone classification and markings

Bone markings—general

- **Head**
  - Expanded proximal end of a bone that forms part of a joint

- **Diaphysis** (shaft)
  - Elongated body of a long bone

- **Neck**
  - Narrow connection between the head and diaphysis of a bone
Bone markings—elevations or projections

- **Process**—any projection or bump
- **Tubercle**—small, rounded projection
- **Tuberosity**—small, rough projection that takes up a broad area
- **Trochlea**—smooth, grooved articular process shaped like a pulley
- **Condyle**—smooth, rounded articular process
Bone markings—elevations or projections (continued)

- **Trochanter**—large, rough projection
- **Facet**—small, flat articular surface
Module 6.2: Bone classification and markings

Bone markings—elevations or projections (continued)

- **Crest**—prominent ridge
- **Line**—low ridge, more delicate than a crest
- **Spine**—pointed or narrow process
- **Ramus**—extension of a bone that makes an angle with the rest of a structure
Module 6.2: Bone classification and markings

Bone markings—depressions, grooves, and tunnels

- **Canal** or **meatus**—large passageway through a bone
- **Sinus**—chamber within a bone, normally filled with air
- **Foramen**—small, rounded passageway for blood vessels or nerves to pass through bone

![Bone Markings of the Skull](image)
Module 6.2: Bone classification and markings

Bone markings—depressions, grooves, and tunnels (continued)

- **Fissure**—elongated cleft or gap
- **Sulcus**—deep, narrow groove
- **Fossa**—shallow depression or recess in bone surface
Module 6.2: Review

A. Identify the six broad categories for classifying a bone according to shape.

B. Define *bone markings*.

C. List the different terms used to describe projections.

*Learning Outcome:* Classify bones according to their shapes, identify the major types of bone markings, and explain the functional significance of bone markings.
Module 6.3: Long bones transmit forces along the shaft and have a rich blood supply

Long bone features

- **Epiphysis** (expanded area at each end of the bone)
  - Consists largely of **spongy bone** (trabecular bone)
  - Outer covering of **compact bone** (cortical bone)
    - Strong, organized bone
- **Articular cartilage**
  - Covers portions of epiphysis that form articulations
Module 6.3: Functional anatomy of a long bone

Long bone features (continued)

- **Metaphysis** (connects epiphysis to shaft)
- **Diaphysis** (shaft)
  - Contains *medullary cavity* (marrow cavity)
    - Filled with two types of marrow
      - **Red bone marrow** (involved in red blood cell production)
      - **Yellow bone marrow** (adipose tissue; important as energy reserve)
Module 6.3: Functional anatomy of a long bone

Growth and maintenance require extensive blood supply

- **Vascular features**
  - **Nutrient artery and nutrient vein** (commonly one of each per bone)
    - **Nutrient foramen** (tunnel providing access to marrow cavity)
  - **Metaphyseal artery and metaphyseal vein**
    - Carry blood to/from metaphysis
    - Connect to epiphyseal arteries/veins
Blood supply and innervation of the periosteum

- Smaller blood vessels supply superficial osteons
- Lymphatic vessels collect lymph from bone and osteons
- Sensory nerves innervate diaphysis, medullary cavity, and epiphyses
Module 6.3: Review

A. List the major parts of a long bone.
B. Describe the function of the medullary cavity.
C. Where is articular cartilage found, and how is it nourished?
D. Why are bone injuries usually painful?

*Learning Outcome*: Identify the parts of a typical long bone, and describe its internal structures.
Module 6.4: Bone has a calcified matrix maintained and altered by osteogenic cells, osteoblasts, osteocytes, and osteoclasts

**Osteogenic cells** (osteoprogenitor cells)
- Mesenchymal (stem) cells that produce cells that differentiate into osteoblasts
  - Important in fracture repair
  - Locations
    - Inner lining of periosteum
    - Lining endosteum in medullary cavity
    - Lining passageways containing blood vessels
Module 6.4: Bone tissue

Osteoblasts (*blast*, precursor)

- Produce new bony matrix (*osteogenesis* or *ossification*)
  - Produces unmineralized matrix (*osteoid*)
  - Then assists in depositing calcium salts to convert osteoid to bone
- Become *osteocytes* once surrounded by bony matrix
Module 6.4: Bone tissue

Osteocytes (osteo-, bone + cyte, cell)
- Mature bone cells that cannot divide
- Maintain protein and mineral content of surrounding matrix
- Occupy lacunae (pockets)
  - Separated by layers of matrix (lamellae)
  - Interconnected by canaliculi
Osteoclasts (*klastos*, broken)

- Remove and remodel bone matrix
- Release acids and proteolytic enzymes to dissolve matrix and release stored minerals
  - Process called **osteolysis** (*lysis*, loosening)
Module 6.4: Bone tissue

Bone matrix

- Collagen fibers account for ~1/3 bone weight
  - Provide flexibility

- Calcium phosphate ($\text{Ca}_3(\text{PO}_4)_2$) accounts for ~2/3 bone weight
  - Interacts with calcium hydroxide ($\text{Ca}(\text{OH})_2$) to form crystals of hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) salts
    - Incorporates other salts (calcium carbonate, $\text{CaCO}_3$) and ions ($\text{Na}^+$, $\text{Mg}^{2+}$, $\text{F}^-$)
    - Provides strength
Module 6.4: Review

A. Describe the functions of osteogenic cells and osteoblasts.

B. Describe the functions of osteocytes.

C. How would the compressive strength of a bone be affected if the ratio of collagen to hydroxyapatite increased?

D. If osteoclast activity exceeds osteoblast activity in a bone, how will the bone mass be affected?

Learning Outcome: Identify the types of cells in bone, and list their major functions.
Module 6.5: Compact bone consists of parallel osteons, and spongy bone consists of a network of trabeculae

Compact bone

- Functional unit is **osteon** (Haversian system)
  - Organized **concentric lamellae** around a **central canal**
    - Osteocytes (in lacunae) lie between lamellae
    - Central canal contains small blood vessels
Module 6.5: Compact and spongy bone structure

Compact bone (continued)
- Functional unit is **osteon** (Haversian system) (continued)
  - Canaliculi connect lacunae with each other and central canal
  - Strong along its length
Module 6.5: Compact and spongy bone structure

Long bone organization

- Periosteum—outermost layer
- Compact bone—outer bone tissue layer
  - Circumferential lamellae (circum-, around + ferre, to bear) at outer and inner surfaces
  - Interstitial lamellae fill spaces between osteons
  - Osteons
    - Connected by perforating canals (perpendicular to surface)
- Spongy bone—innermost layer
Long bone organization
Module 6.5: Compact and spongy bone structure

Spongy bone

- Lamellae form struts and plates (trabeculae) creating an open network
  - No blood vessels in matrix
    - Nutrients reach osteons through canaliculi open to trabeculae surfaces
  - Red bone marrow is found between trabeculae
Module 6.5: Review

A. Define *osteon*.
B. Compare compact bone and spongy bone.
C. A sample of bone has lamellae that are not arranged in osteons. Is the sample more likely from the epiphysis or from the diaphysis?

*Learning Outcome*: Compare the structures and functions of compact bone and spongy bone.
Module 6.6: Appositional bone growth involves the periosteum and the endosteum

Appositional growth in bones

- Increases bone diameter of existing bones
- Osteogenic cells differentiate into osteoblasts that add bone matrix under periosteum
  - Adds successive layers of circumferential lamellae
  - Trapped osteoblasts become osteocytes
Appositional growth

Additional circumferential lamellae are deposited, and the bone continues to increase in diameter.
Appositional growth in bones (continued)

- Deeper lamellae recycled and replaced by osteons
- Osteoclasts remove matrix at inner surface to enlarge medullary cavity
Module 6.6: Appositional bone growth

The periosteum

- Wraps the superficial layer of compact bone
- Two layers
  1. Fibrous outer layer
  2. Cellular inner layer
- Functions
  1. Isolates bone from surrounding tissues
  2. Route for blood and nervous supply
  3. Actively participates in bone growth and repair
- **Perforating fibers** allow for strong attachment
Module 6.6: Appositional bone growth

Endosteum

- Incomplete cellular layer lining medullary cavity
- Active during bone growth, repair, remodeling
- Covers spongy bone and lines central canals
- Where layer is incomplete, exposed matrix is remodeled by osteoclasts and osteoblasts
  - Osteoclasts in shallow depressions called osteoclastic crypts (Howship’s lacunae)
Module 6.6: Review

A. Define *appositional growth*.

B. As a bone increases in diameter, what happens to the medullary cavity?

C. Distinguish between the periosteum and the endosteum.

*Learning Outcome:* Describe the process of appositional bone growth.
Module 6.7: Endochondral ossification replaces a cartilage model with bone

Endochondral ossification

- Initial skeleton of embryo formed of hyaline cartilage
- Cartilage gradually replaced by bone through endochondral (endo-, inside + chondros, cartilage) ossification
  - Uses cartilage as small model
  - Bone grows in diameter and length
    - Diameter growth involves appositional bone deposition
Steps in endochondral ossification

1. Cartilage model enlarges
   - Chondrocytes near center of shaft enlarge
   - Enlarged chondrocytes die and disintegrate
   - Disintegration leaves cavities within cartilage
Module 6.7: Endochondral ossification

Steps in endochondral ossification (continued)

2. Blood vessels grow around the edge of the cartilage model
   • Cells of perichondrium convert to osteoblasts
   • Osteoblasts form superficial layer of bone along the shaft
Steps in endochondral ossification (continued)

3. Blood vessels penetrate cartilage and enter central region
   • Entering fibroblasts differentiate into osteoblasts
   • Begin spongy bone production at **primary ossification center**
   • Bone formation spreads along the shaft toward both ends
Module 6.7: Endochondral ossification

Steps in endochondral ossification (continued)

4. Growth continues along with remodeling
   - Medullary cavity created
   - Osseous tissue of the shaft thickens
   - Cartilage near the epiphyses is replaced by shafts of bone
   - Bone grows in length and diameter
5. Capillaries and osteoblasts migrate into the epiphyses
   • Create **secondary ossification centers**
6. Epiphyses fill with spongy bone
   • Articular cartilage remains exposed to joint cavity
   • Epiphyseal cartilage (epiphyseal plate) separates epiphysis from diaphysis
Steps in endochondral ossification (continued)

7. Bone grows in length at the epiphyseal cartilage
   • Chondrocytes actively produce more cartilage on epiphyseal side
   • Osteoblasts actively replace cartilage with bone on diaphyseal side
   • Epiphyses are pushed away by continued production of new cartilage
Endochondral ossification
Module 6.7: Endochondral ossification

Bone growth
- At puberty, hormones stimulate increased bone growth, and epiphyseal cartilage is replaced
  - Osteoblasts produce bone faster than chondrocytes produce cartilage
  - Epiphyseal cartilage narrows until it disappears
    - Process called **epiphyseal closure**
    - Leaves **epiphyseal line** in adults
Module 6.7: Review

A. Define *endochondral ossification*.

B. In endochondral ossification, what is the original source of osteoblasts?

C. How could x-rays of the femur be used to determine whether a person has reached full height?

*Learning Outcome:* Describe the process of endochondral ossification.
Module 6.8: Intramembranous ossification forms bone without a prior cartilage model

- Begins when mesenchymal (stem) cells differentiate into osteoblasts within embryonic or fibrous connective tissue
- Normally occurs in deeper layers of dermis
- Bones called **dermal bones** or membrane bones
- *Examples*: roofing bones of skull, lower jaw, collarbone, sesamoid bones (patella)
Module 6.8: Intramembranous ossification

Steps of intramembranous ossification

1. Mesenchymal cells cluster
   - Differentiate into osteoblasts
     - Secrete osteoid matrix
   - Osteoid matrix becomes mineralized
     - Forms bone matrix

- Location in tissue where ossification begins is ossification center
Module 6.8: Intramembranous ossification

Steps of intramembranous ossification (continued)

2. Bone grows out in small struts (spicules)
   - Osteoblasts become trapped in pockets and mature into osteocytes
   - Mesenchymal cells produce more osteoblasts
Module 6.8: Intramembranous ossification

Steps of intramembranous ossification (continued)

3. Blood vessels enter area
   • Bone spicules meet and fuse
   • Blood vessels trapped in developing bone
Module 6.8: Intramembranous ossification

Steps of intramembranous ossification (continued)

4. Continued deposition of bone by osteoblasts close to blood vessel
   • Results in spongy bone with interwoven blood vessels
Steps of intramembranous ossification (continued)

5. Remodeling around blood vessels produces osteons of compact bone
   - Connective tissue around bone organizes into fibrous layer of the periosteum
   - Osteoblasts near bone surface remain as cellular layer of periosteum
Intramembranous ossification
Module 6.8: Intramembranous ossification

Intramembranous ossification in development

- Begins during the eighth week of embryonic development
- Can see ossification centers and progressing bone formation at 10 weeks
- At 16 weeks, most of the bones of the adult skeleton can be identified
Module 6.8: Review

A. Define *intramembranous ossification*.

B. During intramembranous ossification, bone replaces which type of tissue?

C. Explain the primary difference between endochondral ossification and intramembranous ossification.

*Learning Outcome:* Describe the process of intramembranous ossification.
Module 6.9: CLINICAL MODULE: Abnormalities of bone growth and development produce recognizable physical signs

Disorders causing shortened bones

- Pituitary growth failure
  - Inadequate growth hormone production
  - Reduced epiphyseal cartilage activity; abnormally short bones
  - Rare in United States due to treatment with synthetic growth hormone
Disorders causing shortened bones (continued)

- **Achondroplasia**
  - Epiphyseal cartilage of long bones grows slowly
    - Replaced by bone early in life
  - Short, stocky limbs result
  - Trunk is normal size
  - No effects on sexual or mental development
Module 6.9: CLINICAL MODULE: Abnormalities of bone growth

Disorders causing lengthened bones

- **Marfan syndrome**
  - Inherited metabolic condition
  - Excessive cartilage formation at epiphyseal cartilages
  - Results in very tall person with long, slender limbs
  - Affects other connective tissues throughout the body
    - Commonly causes cardiovascular problems
Other skeletal growth abnormalities

- Congenital talipes equinovarus (clubfoot)
  - Inherited developmental abnormality
    - Affects 2 in 1000 births
    - Boys roughly twice as often as girls
  - May affect one or both feet
  - Abnormal muscle development distorts growing bones
    - Feet turn medially and are inverted
  - Treated with casts or supports
Module 6.9: CLINICAL MODULE: Abnormalities of bone growth

Gigantism

- Disorder causing lengthened bones
- Overproduction of growth hormone before puberty
- Can reach heights of over 2.7 m (8 ft. 11 in.)
- Puberty often delayed
- Most common cause is a pituitary tumor
- Treated by surgery, radiation, or medications suppressing growth hormone release
Module 6.9: CLINICAL MODULE: Abnormalities of bone growth

Other skeletal growth abnormalities

- Fibrodysplasia ossificans progressiva (FOP)
  - Gene mutation that causes bone deposition around skeletal muscles
  - Bones develop in unusual places
    - Called heterotopic (*hetero*, place) or ectopic (*ektos*, outside) bones
  - No effective treatment
Other skeletal growth abnormalities (continued)

- **Acromegaly**
  - Overproduction of growth hormone after epiphyseal plates close
  - Bones get thicker, not longer
    - Especially those in face, jaw, and hands
  - Alterations in soft-tissue structure changes physical features
Module 6.9: Review

A. Why is pituitary growth failure less common today in the United States?
B. Describe Marfan syndrome.
C. Compare gigantism with acromegaly.

Learning Outcome: Discuss various abnormalities of bone formation and growth.
Section 2: Physiology of Bones

Learning Outcomes

6.10 List the minerals stored in the bones, and identify the organs involved in calcium homeostasis.

6.11 Discuss the effects of hormones on bone development, and explain the homeostatic mechanisms involved.

6.12 **Clinical Module:** Describe the types of fractures, and explain how fractures heal.
Module 6.10: Bones play an important role as mineral reservoirs

Minerals

- Inorganic ions contributing to the osmotic balance of body fluids
- Vital in many physiological processes

<table>
<thead>
<tr>
<th>Bone Composition</th>
<th>Bone Contains</th>
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<tbody>
<tr>
<td>Organic compounds</td>
<td>99% of the body’s calcium</td>
</tr>
<tr>
<td>(mostly collagen)</td>
<td>4% of the body’s potassium</td>
</tr>
<tr>
<td>33%</td>
<td>35% of the body’s sodium</td>
</tr>
<tr>
<td>Calcium 39%</td>
<td>50% of the body’s magnesium</td>
</tr>
<tr>
<td>Potassium 0.2%</td>
<td>80% of the body’s carbonate</td>
</tr>
<tr>
<td>Sodium 0.7%</td>
<td>99% of the body’s phosphate</td>
</tr>
<tr>
<td>Magnesium 0.4%</td>
<td></td>
</tr>
<tr>
<td>Carbonate 9.7%</td>
<td></td>
</tr>
<tr>
<td>Phosphate 17%</td>
<td></td>
</tr>
</tbody>
</table>

Total inorganic components 67%
Module 6.10: Bones as mineral reservoirs

The importance of calcium

- Most abundant mineral in body
- 1–2 kg (2.2–4.4 lb)
- ~99 percent deposited in skeleton
- Variety of physiological functions (muscle contraction, blood coagulation, nerve impulse generation)
  - Concentration variation greater than 30–35 percent affects neuron and muscle function
  - Normal daily fluctuations are <10 percent
Maintaining calcium levels

- Controlled by activities of:
  - Intestines
    - Absorb calcium and phosphate under hormonal control
  - Bones
    - Osteoclasts erode matrix and release calcium
    - Osteoblasts use calcium to deposit new matrix
  - Kidneys
    - Varying levels of calcium and phosphate loss in urine under hormonal control
Calcium level maintenance

In the intestines, calcium and phosphate ions are absorbed from the diet. The absorption rate is hormonally regulated.

Within the skeleton, osteoblasts continuously deposit new bone matrix. At the same time, osteoclasts erode existing matrix, releasing calcium and phosphate ions into the circulation. The balance between osteoblast and osteoclast activity is hormonally regulated.

In the kidneys, the levels of calcium and phosphate ions lost in the urine are hormonally regulated.
Module 6.10: Review

A. What is the ratio of organic compounds to inorganic components in the composition of bone?

B. Which three organ systems coordinate to maintain normal blood calcium levels?

C. What physical signs would be expected in a person whose blood calcium was abnormally low?

*Learning Outcome:* List the minerals stored in the bones, and identify the organs involved in calcium homeostasis.
Module 6.11: The primary hormones regulating calcium ion metabolism are parathyroid hormone, calcitriol, and calcitonin

Factors that increase blood calcium levels

- Parathyroid hormone (PTH)
  - Secreted from parathyroid glands
  - Responses
    - In bones:
      - Osteoclasts stimulated to erode matrix, releasing stored calcium
Factors that increase blood calcium levels (continued)

- **Parathyroid hormone (PTH)** (continued)
  
  - Responses (continued)
    - In intestines:
      - Calcitriol effects enhanced and calcium absorption increased
    - In kidneys:
      - Increased release of hormone *calcitriol*, stimulating calcium reabsorption in kidneys
Parathyroid hormone and calcium

Factors That Increase Blood Calcium Level

These responses are triggered when blood calcium ion concentration falls below 8.5 mg/dL (1 dL equals 0.1 L, or 100 mL).

Low Calcium Ion Level in Blood (below 8.5 mg/dL)

Parathyroid Gland Response

Low calcium level causes the parathyroid glands to secrete parathyroid hormone (PTH).

PTH

Bone Response

Osteoclast

Bone

Osteoclasts do not have PTH receptors. The PTH does bind to adjacent osteoblasts, which causes them to release a hormone (RANKL [receptor activator of nuclear factor kappa-B ligand]) that stimulates immature osteoclasts to differentiate into mature osteoclasts. These mature osteoclasts erode the bone matrix, thereby releasing stored calcium ions.

Intestinal Response

PTH enhances the calcium-absorbing effects of calcitriol on the intestines. As a result, the rate of intestinal calcium absorption increases.

Kidney Response

PTH increases renal production of the hormone calcitriol. Under normal circumstances, a low level of calcitriol is always present because it is secreted continuously by the kidneys. Calcitriol stimulates calcium reabsorption by the kidneys and calcium absorption in the intestines.

Calcium released

Calcium absorbed quickly

Calcium conserved

Ca^{2+} level in blood increases

Less calcium lost in urine
Module 6.11: Hormones regulating calcium ion metabolism

Factors that decrease blood calcium levels

- **Calcitonin**
  - Secreted from **C cells** in the **thyroid gland**
  - **Responses**
    - **In bones:**
      - Osteoclast activity inhibited; calcium deposited in bone matrix
    - **In intestines:**
      - Calcium absorption decreased with decreasing PTH and calcitriol
    - **In kidneys:**
      - Inhibits calcitriol release and calcium reabsorption
Thyroid regulation of calcium

Factors That Decrease Blood Calcium Level

Intestinal and kidney responses are triggered when blood calcium ion concentration rises above 11 mg/dL.

High Calcium Ion Level in Blood (above 11 mg/dL)

Thyroid Gland Response

C cells in the thyroid gland secrete calcitonin.

Calcitonin

Bone Response

Bone

Calcitonin decreases osteoclast activity but does not affect osteoblasts, which continue to deposit calcium ions within the bone matrix.

Intestinal Response

Calcium absorbed slowly

Decreasing PTH or calcitriol level results in a decrease in the rate of calcium ion absorption by the intestines.

Kidney Response

Calcium excreted

Increased calcitonin level has an inhibitory effect on the kidneys and suppresses calcium ion reabsorption.

Less calcitriol

More calcium lost in urine

Calcium release slowed

Ca^{2+} level in blood decreases
Module 6.11: Hormones regulating calcium ion metabolism

Calcium and the skeleton

- As a calcium reserve, skeleton has primary role in calcium homeostasis
- Has direct effect on shape and strength of bones
  - Release of calcium into blood weakens bones
  - Deposition of calcium salts strengthens bones
Module 6.11: Review

A. Identify the hormone that stimulates the release of calcium ions from bone matrix. Explain its mechanism of action.

B. Describe the kidney and intestinal responses to PTH.

C. How does calcitonin act to lower blood calcium?

Learning Outcome: Discuss the effects of hormones on bone development, and explain the homeostatic mechanisms involved.
Module 6.12: CLINICAL MODULE: A fracture is a crack or a break in a bone

Fracture

- Crack or break due to extreme mechanical stress
- Most heal as long as blood supply and cellular parts of periosteum and endosteum survive
- Repair involves four steps
Module 6.12: CLINICAL MODULE: Bone fractures

Steps in fracture repair

1. Fracture hematoma formation
   - Large clot closes injured vessels
   - Develops within several hours

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Steps in fracture repair (continued)

2. Callus formation
   - **Internal callus**
     - Network of spongy bone
     - Unites inner edges of fracture
   - **External callus**
     - Composed of cartilage and bone
     - Stabilizes outer edges of fracture
Steps in fracture repair (continued)

3. Spongy bone formation
   - Cartilage of external callus replaced by spongy bone
   - Bone fragments and dead bone are removed and replaced
   - Ends of fracture held firmly in place
Steps in fracture repair (continued)

4. Compact bone formation
   - Spongy bone replaced by compact bone
   - Remodeling over time eliminates evidence of fracture
Module 6.12: CLINICAL MODULE: Bone fractures

General categories of fractures

- **Closed or simple**
  - Completely internal (no break in skin)
  - Only seen on x-rays

- **Open or compound**
  - Project through the skin
  - More dangerous due to:
    - Infection
    - Uncontrolled bleeding
Module 6.12: CLINICAL MODULE: Bone fractures

Specific types of fractures

- **Transverse fractures**
  - Break shaft across long axis

- **Spiral fractures**
  - Produced by twisting stresses
  - Spread along length of bone
Specific types of fractures (continued)

- **Displaced fractures**
  - Produce new and abnormal bone arrangements
  - **Nondisplaced fractures** retain normal alignment

- **Compression fractures**
  - Occur in vertebrae subjected to extreme stresses
  - Often associated with osteoporosis
Specific types of fractures (continued)

- Greenstick fractures
  - One side of shaft broken, one side bent
  - Generally occurs in children
    - Long bones have yet to fully ossify

- Comminuted fractures
  - Shatter affected area producing fragments
Specific types of fractures (continued)

- **Epiphyseal fractures**
  - Occur where bone matrix is calcifying
  - A clean transverse fracture of this type heals well
  - If not monitored, breaks between epiphyseal plate and cartilage can stop growth at site
Module 6.12: CLINICAL MODULE: Bone fractures

Specific types of fractures (continued)

- **Pott’s (bimalleolar) fracture**
  - Occurs at ankle and affects both medial malleolus and lateral malleolus

- **Colles fracture**
  - Break in distal radius
Module 6.12: Review

A. List the steps involved in fracture repair, beginning just after the fracture occurs.

B. Define *open fracture* and *closed fracture*.

*Learning Outcome:* Describe the types of fractures, and explain how fractures heal.