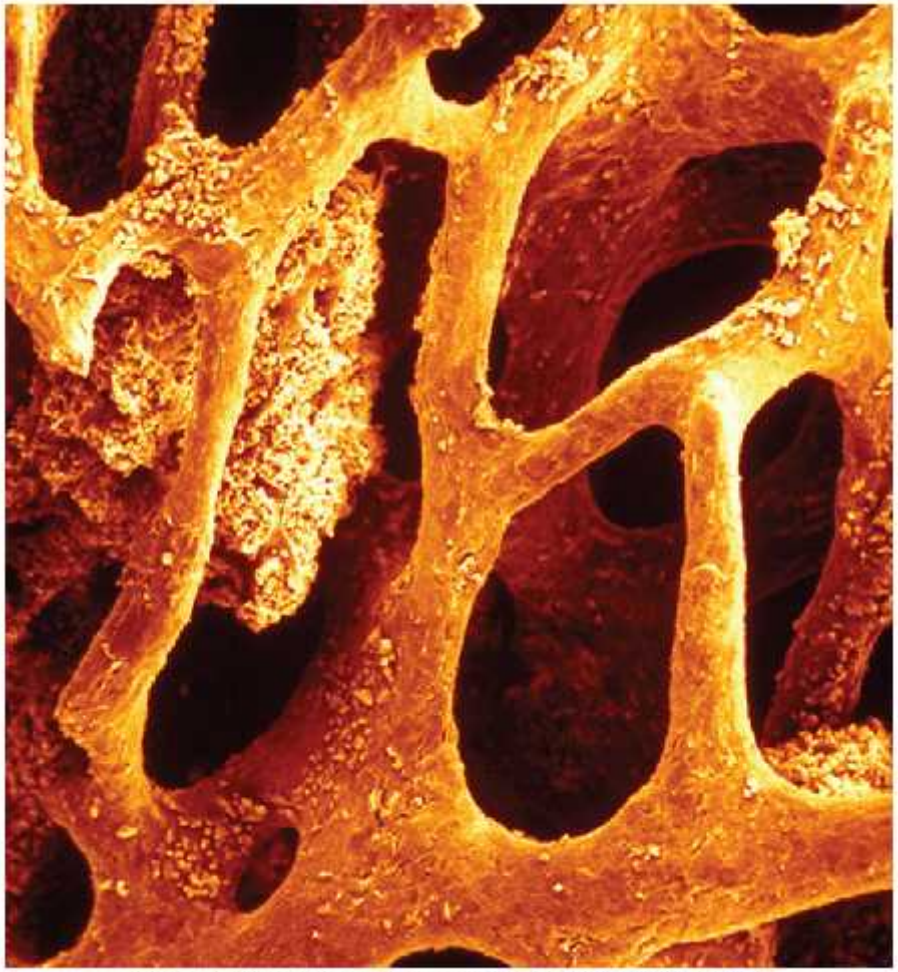

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Chapter 7

*Lecture PowerPoint

Bone Tissue

*See separate *FlexArt PowerPoint* slides for all figures and tables preinserted into PowerPoint without notes.

Introduction

- **In this chapter we will cover:**
  - Bone tissue composition
  - How bone functions, develops, and grows
  - How bone metabolism is regulated and some of its disorders

Introduction

- Bones and teeth are the most durable remains of a once-living body and the most vivid reminder of life
- Living skeleton is made of dynamic tissues, full of cells, permeated with nerves and blood vessels
- Osteology is the study of bone

Tissues and Organs of the Skeletal System

- **Expected Learning Outcomes**
  - Name the tissues and organs that compose the skeletal system.
  - State several functions of the skeletal system.
  - Distinguish between bones as a tissue and as an organ.
  - Describe the four types of bones classified by shape.
  - Describe the general features of a long bone and a flat bone.

Tissues and Organs of the Skeletal System

- **Osteology**—the study of bone
- **Skeletal system**—composed of bones, cartilages, and ligaments
  - Form strong, flexible framework of the body
  - **Cartilage**—forerunner of most bones
    - Covers many joint surfaces of mature bone
- **Ligaments**—hold bones together at the joints
- **Tendons**—attach muscle to bone

Functions of the Skeleton

- **Support**—holds up the body, supports muscles, mandible and maxilla support teeth
- **Protection**—brain, spinal cord, heart, lungs
- **Movement**—limb movements, breathing, action of muscle on bone
- **Electrolyte balance**—calcium and phosphate ions
- **Acid–base balance**—buffers blood against excessive pH changes
- **Blood formation**—red bone marrow is the chief producer of blood cells

Bones and Osseous Tissue

- **Bone (osseous tissue)**—connective tissue with the matrix hardened by calcium phosphate and other minerals
- **Mineralization** or **calcification**—the hardening process of bone
- Individual bones consist of bone tissue, bone marrow, cartilage, adipose tissue, nervous tissue, and fibrous connective tissue
- Continually remodels itself and interacts physiologically with all of the other organ systems of the body
- Permeated with nerves and blood vessels, which attests to its sensitivity and metabolic activity

General Features of Bones

- **Flat bones**
  - Protect soft organs
  - Curved but wide and thin
- **Long bones**
  - Longer than wide
  - Rigid levers acted upon by muscles
- **Short bones**
  - Equal in length and width
  - Glide across one another in multiple directions
- **Irregular bones**
  - Elaborate shapes that do not fit into other categories

General Features of Bones

- **Compact (dense) bone**—outer shell of long bone
- **Diaphysis (shaft)**—cylinder of compact bone to provide leverage
- **Medullary cavity (marrow cavity)**—space in the diaphysis of a long bone that contains bone marrow
- **Epiphyses**—enlarged ends of a long bone
  - Enlarged to strengthen joint and attach ligaments and tendons
- **Spongy (cancellous) bone**—covered by more durable compact bone
  - Skeleton three-fourths compact and one-fourth spongy bone by weight
  - Spongy bone in ends of long bones, and middle of nearly all others

General Features of Bones

- **Spongy (cancellous) bone**—covered by more durable compact bone
  - Skeleton three-fourths compact and one-fourth spongy bone by weight
  - Spongy bone in ends of long bones, and middle of nearly all others
- **Articular cartilage**—layer of hyaline cartilage that covers the joint surface where one bone meets another; allows joint to move more freely and relatively friction free
- **Nutrient foramina**—minute holes in the bone surface that allows blood vessels to penetrate

General Features of Bones

- **Periosteum**—external sheath that covers bone except where there is articular cartilage
  - **Outer fibrous layer** of collagen
    - Some outer fibers continuous with the tendons that attach muscle to bone
    - **Perforating (Sharpey) fibers**—other outer fibers that penetrate into the bone matrix
    - Strong attachment and continuity from muscle to tendon to bone
  - **Inner osteogenic layer** of bone-forming cells
    - Important to growth of bone and healing of fractures

General Features of Bones

- **Endosteum**—thin layer of reticular connective tissue lining marrow cavity
  - Has cells that dissolve osseous tissue and others that deposit it
- **Epiphyseal plate (growth plate)**—area of **hyaline cartilage** that separates the marrow spaces of the epiphysis and diaphysis
  - Enables growth in length
  - **Epiphyseal line—**in adults, a bony scar that marks where growth plate used to be

General Features of Bones

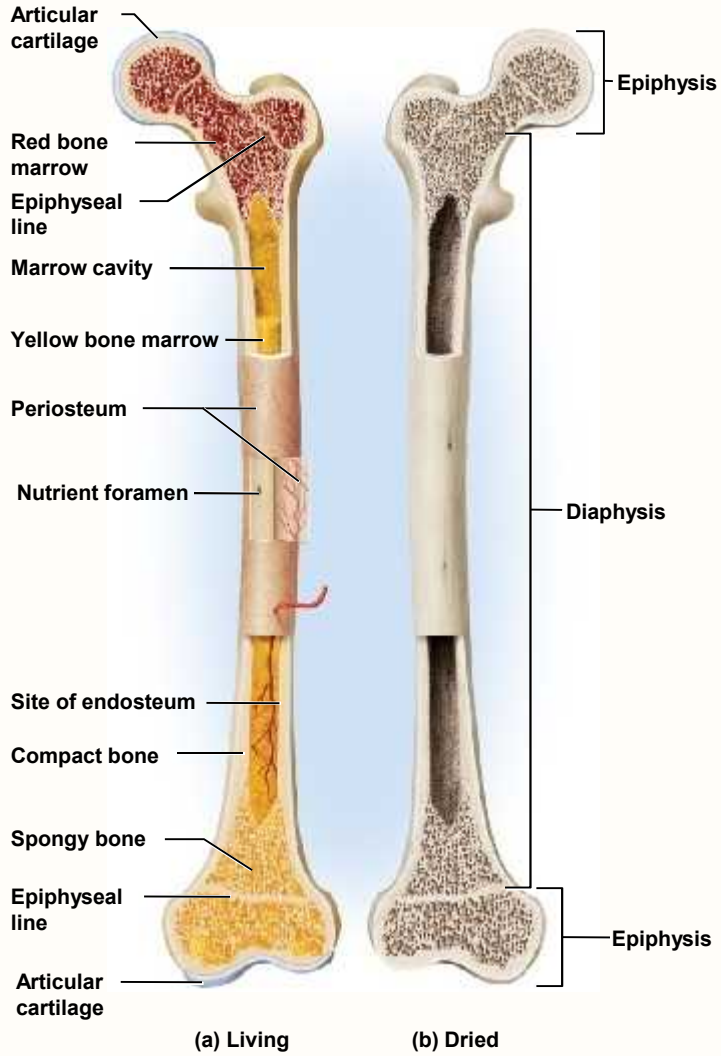


Figure 7.1

- Epiphyses and diaphysis
- Compact and spongy bone
- Marrow cavity
- Articular cartilage
- Periosteum

General Features of Bones

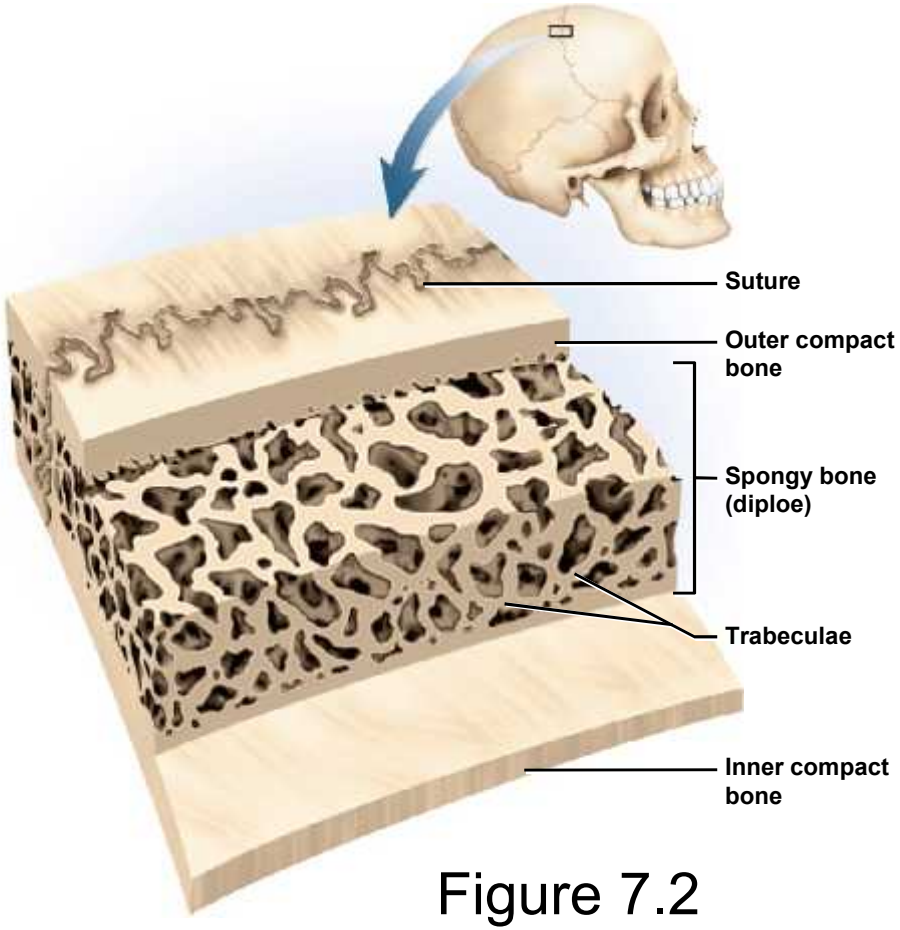


Figure 7.2

- Sandwich-like construction
- Two layers of compact bone enclosing a middle layer of spongy bone
  - Both surfaces of flat bone covered with periosteum
- **Diploe**—spongy layer in the cranium
  - Absorbs shock
  - Marrow spaces lined with endosteum

Histology of Osseous Tissue

- **Expected Learning Outcomes**
  - List and describe the cells, fibers, and ground substance of bone tissue.
  - State the importance of each constituent of bone tissue.
  - Compare the histology of the two types of bone tissue.
  - Distinguish between the two types of bone marrow.

Bone Cells

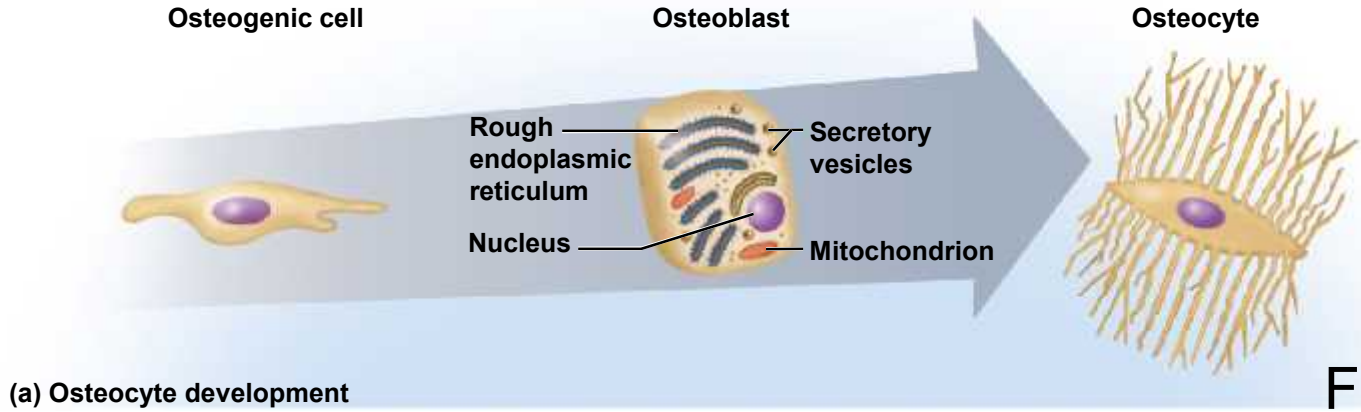


Figure 7.3a

- **Bone** is connective tissue that consists of cells, fibers, and ground substance

- **Four principal types** of bone cells
  - **Osteogenic cells; osteoblasts; osteocytes; osteoclasts**

Bone Cells

- **Osteogenic (osteoprogenitor) cells**—stem cells found in endosteum, periosteum, and in central canals
  - Arise from embryonic mesenchymal cells; multiply continuously to produce new osteoblasts
- **Osteoblasts**—bone-forming cells
  - Line up as single layer of cells under endosteum and periosteum
  - Nonmitotic
  - Synthesize soft organic matter of matrix which then hardens by mineral deposition

Bone Cells

Cont.

- Stress and fractures stimulate osteogenic cells to multiply more rapidly and increase number of osteocytes to reinforce or rebuild bone
- Secrete **osteocalcin—**thought to be the structural protein of bone
  - Stimulates insulin secretion of pancreas
  - Increases insulin sensitivity in adipocytes which limit the growth of adipose tissue

Bone Cells

- **Osteocytes**—former osteoblasts that have become trapped in the matrix they have deposited
  - **Lacunae**—tiny cavities where osteocytes reside
  - **Canaliculi**—little channels that connect lacunae
  - **Cytoplasmic processes** reach into canaliculi
  - Some osteocytes reabsorb bone matrix while others deposit it
  - Contribute to homeostatic mechanism of bone density and calcium and phosphate ions
  - When stressed, produce biochemical signals that regulate bone remodeling

Bone Cells

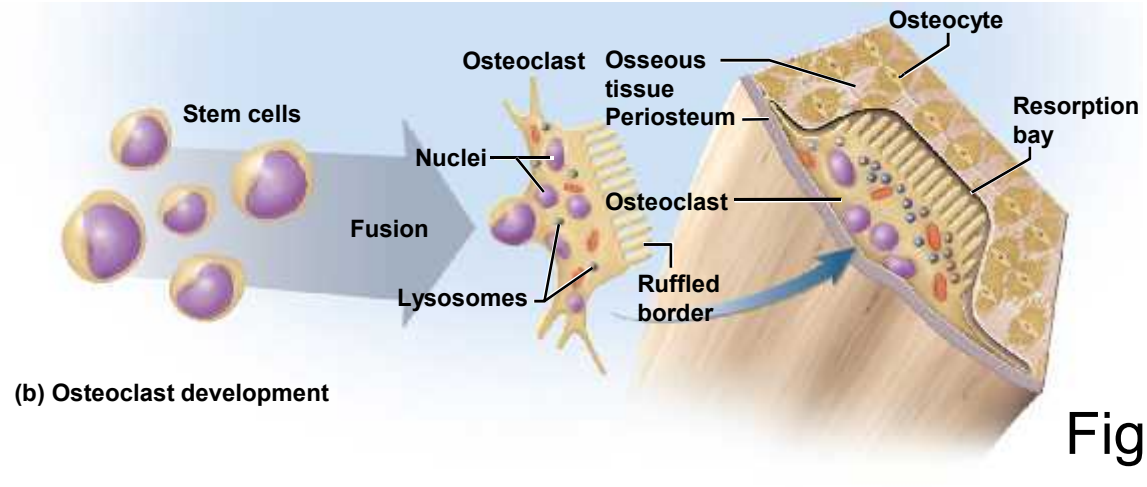


Figure 7.3b

- **Osteoclasts**—bone-dissolving cells found on the bone surface
  - Osteoclasts develop from same bone marrow stem cells that give rise to blood cells
  - Different origin from rest of bone cells
  - Unusually large cells formed from the fusion of several stem cells
    - Typically have 3 to 4 nuclei, may have up to 50

Bone Cells

- **Ruffled border**—side facing bone surface
  - Several deep infoldings of the plasma membrane which increases surface area and resorption efficiency
- **Resorption bays** (Howship lacunae)—pits on surface of bone where osteoclasts reside
- **Remodeling**—results from combined action of the bone-dissolving osteoclasts and the bone-depositing osteoblasts

The Matrix

- **Matrix of osseous tissue** is, by dry weight, about one-third organic and two-thirds inorganic matter
- **Organic matter**—synthesized by osteoblasts
  - Collagen, carbohydrate–protein complexes, such as glycosaminoglycans, proteoglycans, and glycoproteins
- **Inorganic matter**
  - 85% hydroxyapatite (crystallized calcium phosphate salt)
  - 10% calcium carbonate
  - Other minerals (fluoride, sodium, potassium, magnesium)

The Matrix

- Bone is a **composite**—combination of two basic structural materials, a ceramic and a polymer
  - Combines optimal mechanical properties of each component
  - Bone combines the polymer, collagen, with the ceramic, hydroxyapatite and other minerals
  - Ceramic portion allows the bone to support the body weight, and protein portion gives bone some degree of flexibility

The Matrix

- **Rickets**—soft bones due to deficiency of calcium salts
- **Osteogenesis imperfecta** or brittle bone disease—excessively brittle bones due to lack of protein, collagen

Histology of Osseous Tissue

Figure 7.4a

Figure 7.4c

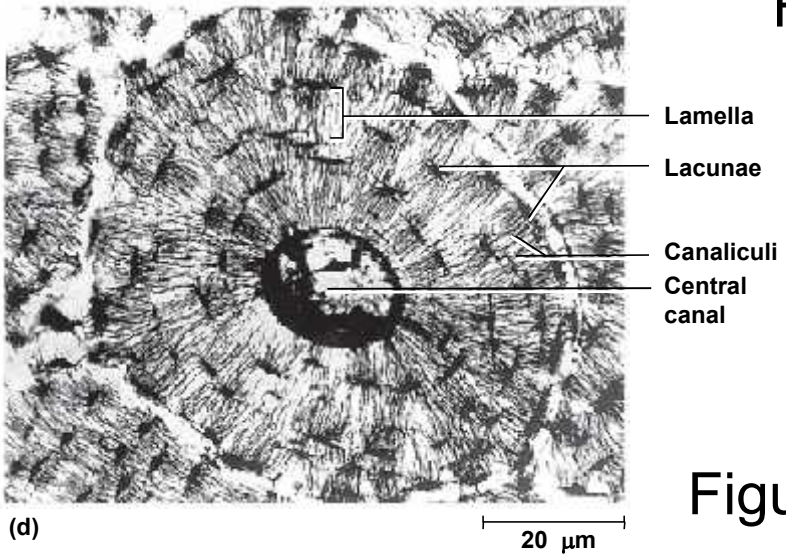


Figure 7.4d

Histology of Osseous Tissue

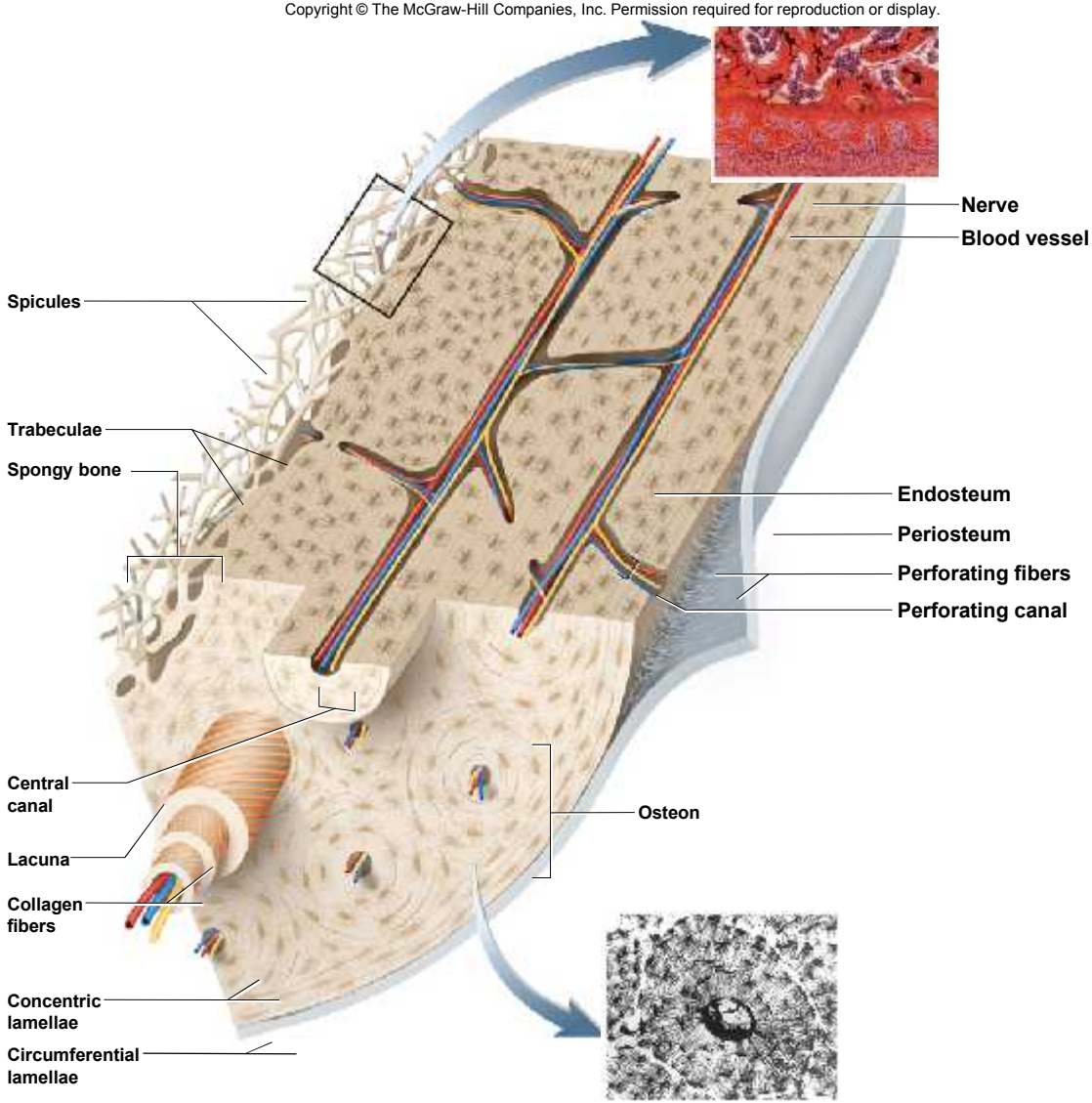


Figure 7.4b,c,d

- **Nutrient foramina**—on bone surface
- **Perforating (Volkmann) canals**—transverse or diagonal canals
- **Central canals**—vertical canals
- Circumferential lamellae
- Interstitial lamellae

Spongy Bone

- Spongelike appearance
- Spongy bone consists of:
  - Slivers of bone called **spicules**
  - Thin plates of bone called **trabeculae**
  - Spaces filled with **red bone marrow**
- Few osteons and no central canals
  - All osteocytes close to bone marrow
- Provides strength with minimal weight
  - Trabeculae develop along bone's **lines of stress**

Spongy Bone Structure in Relation to Mechanical Stress

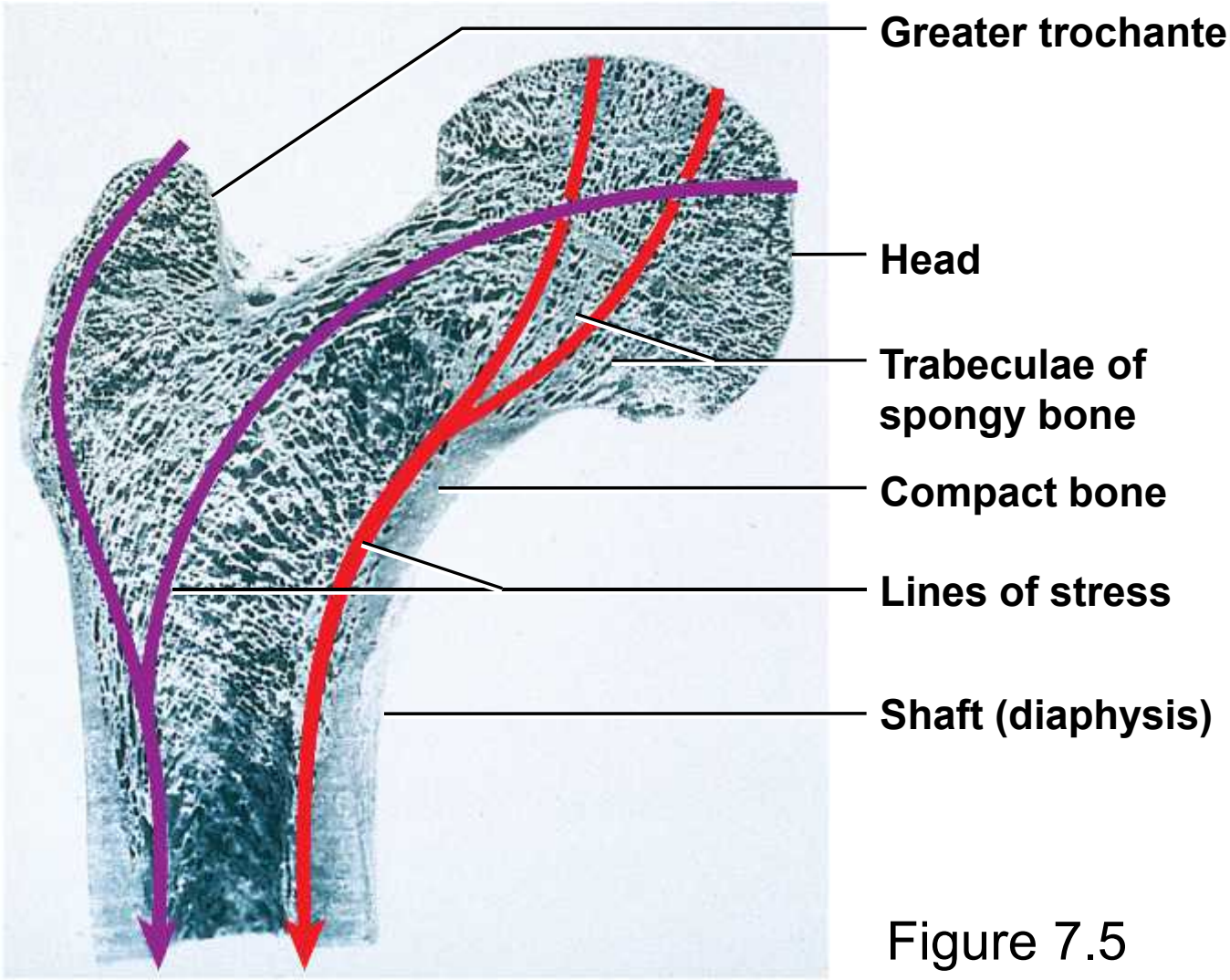


Figure 7.5

Bone Marrow

- **Bone marrow**—general term for soft tissue that occupies the marrow cavity of a long bone and small spaces amid the trabeculae of spongy bone

Figure 7.6

Bone Marrow

- **Red marrow (myeloid tissue)**
  - In nearly every bone in a child
  - **Hemopoietic tissue**—produces blood cells and is composed of multiple tissues in a delicate, but intricate arrangement that is an organ to itself
  - In adults, found in **skull, vertebrae, ribs, sternum,** part of **pelvic girdle,** and **proximal heads of humerus and femur**
- **Yellow marrow** found in adults
  - Most red marrow turns into fatty yellow marrow
  - No longer produces blood

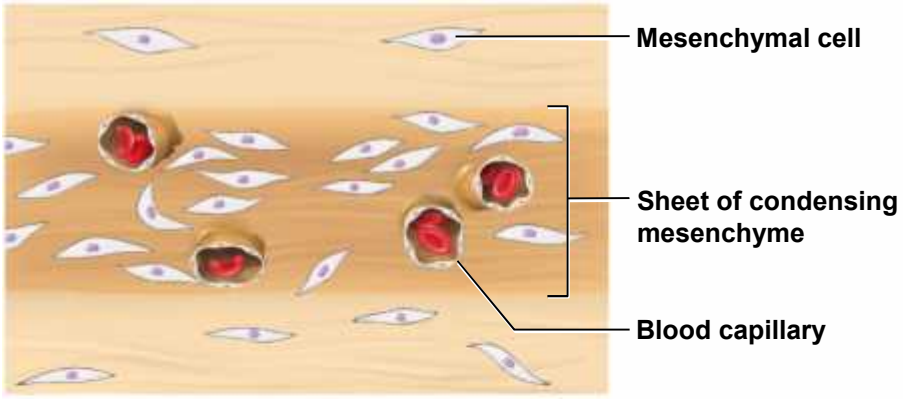
Bone Development

- **Expected Learning Outcomes**
  - Describe two mechanisms of bone formation.
  - Explain how mature bone continues to grow and remodel itself.

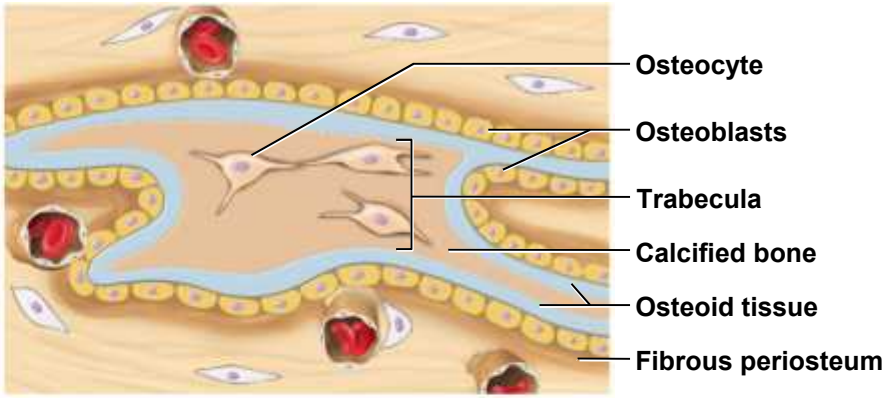
Bone Development

- **Ossification** or **osteogenesis**—the formation of bone
- In the human fetus and infant, bone develops by **two methods**
  - **Intramembranous ossification**
  - **Endochondral ossification**

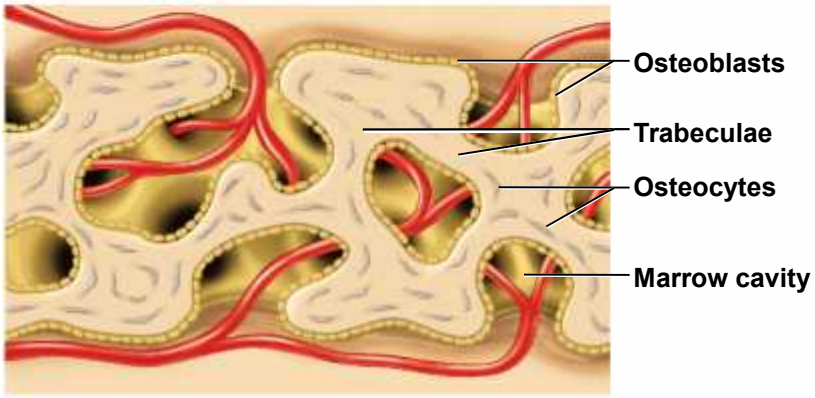
Intramembranous Ossification



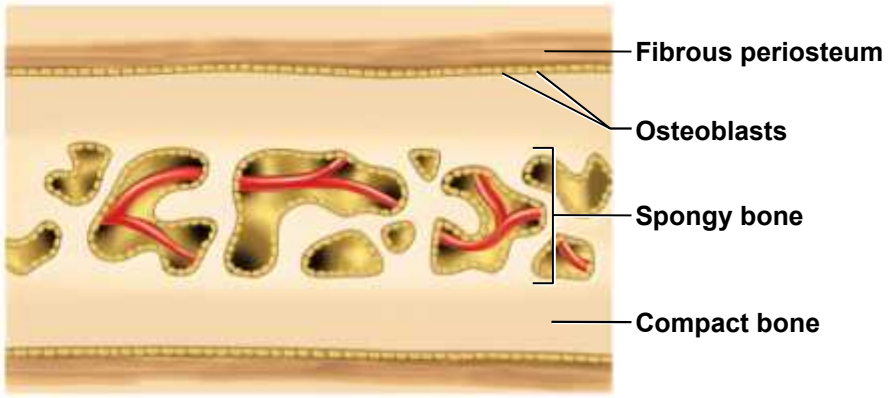
1 Condensation of mesenchyme into soft sheet permeated with blood capillaries



2 Deposition of osteoid tissue by osteoblasts on mesenchymal surface; entrapment of first osteocytes; formation of periosteum



3 Honeycomb of bony trabeculae formed by continued mineral deposition; creation of spongy bone



4 Surface bone filled in by bone deposition, converting spongy bone to compact bone. Persistence of spongy bone in the middle layer.

Figure 7.7

- **Produces flat bones of skull and clavicle**

Intramembranous Ossification

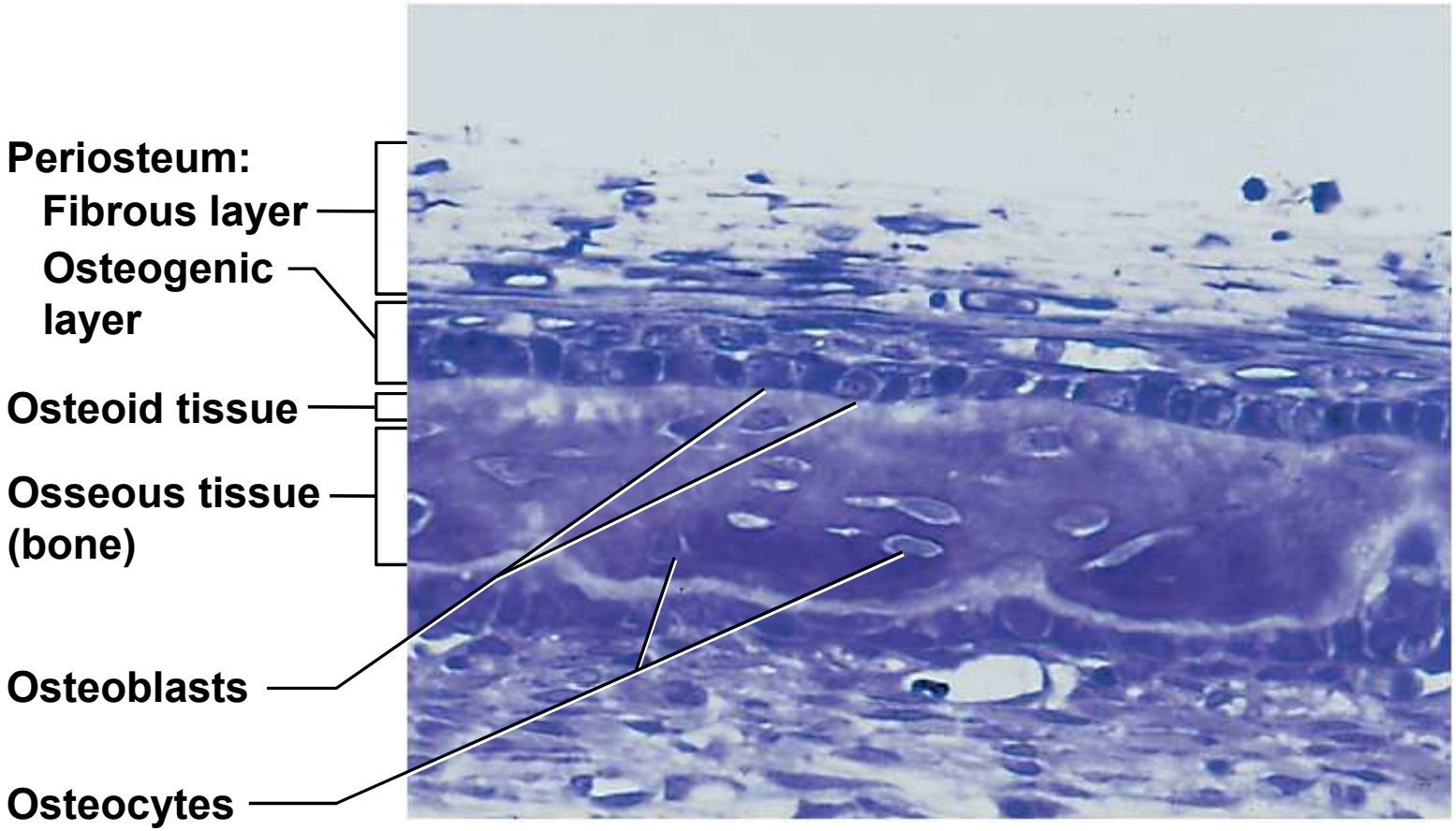


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Figure 7.8

- **Note the periosteum and osteoblasts**

Endochondral Ossification

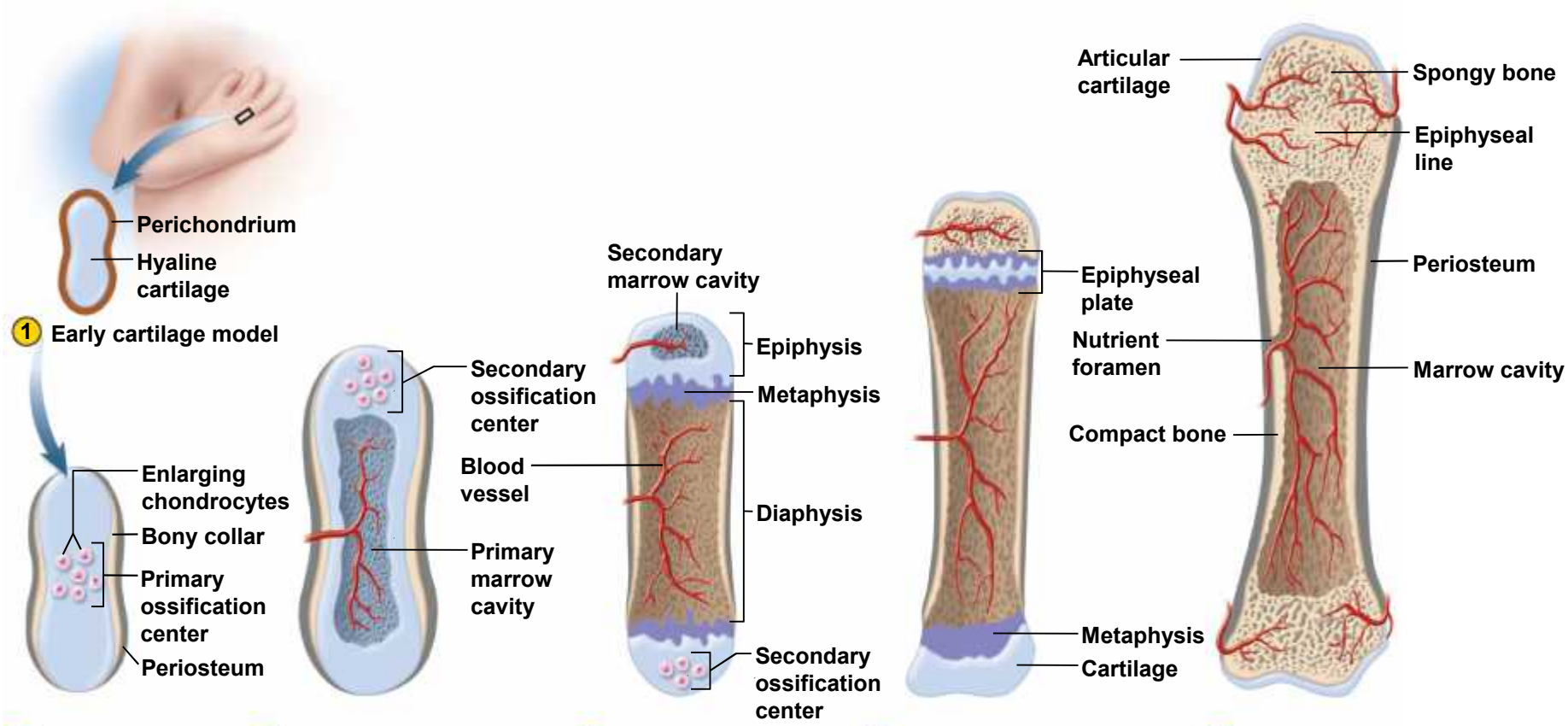


Figure 7.9

Endochondral Ossification

- During infancy and childhood, the epiphyses fill with spongy bone
- Cartilage limited to the **articular cartilage** covering each joint surface, and to the **epiphyseal plate**
  - A thin wall of cartilage separating the primary and secondary marrow cavities
  - Epiphyseal plate persists through childhood and adolescence
  - Serves as a growth zone for bone elongation

Endochondral Ossification

- By late teens to early 20s, all remaining cartilage in the epiphyseal plate is generally consumed
  - Gap between epiphyses and diaphysis closes
  - Primary and secondary marrow cavities unite into a single cavity
  - Bone can no longer grow in length

The Fetal Skeleton at 12 Weeks

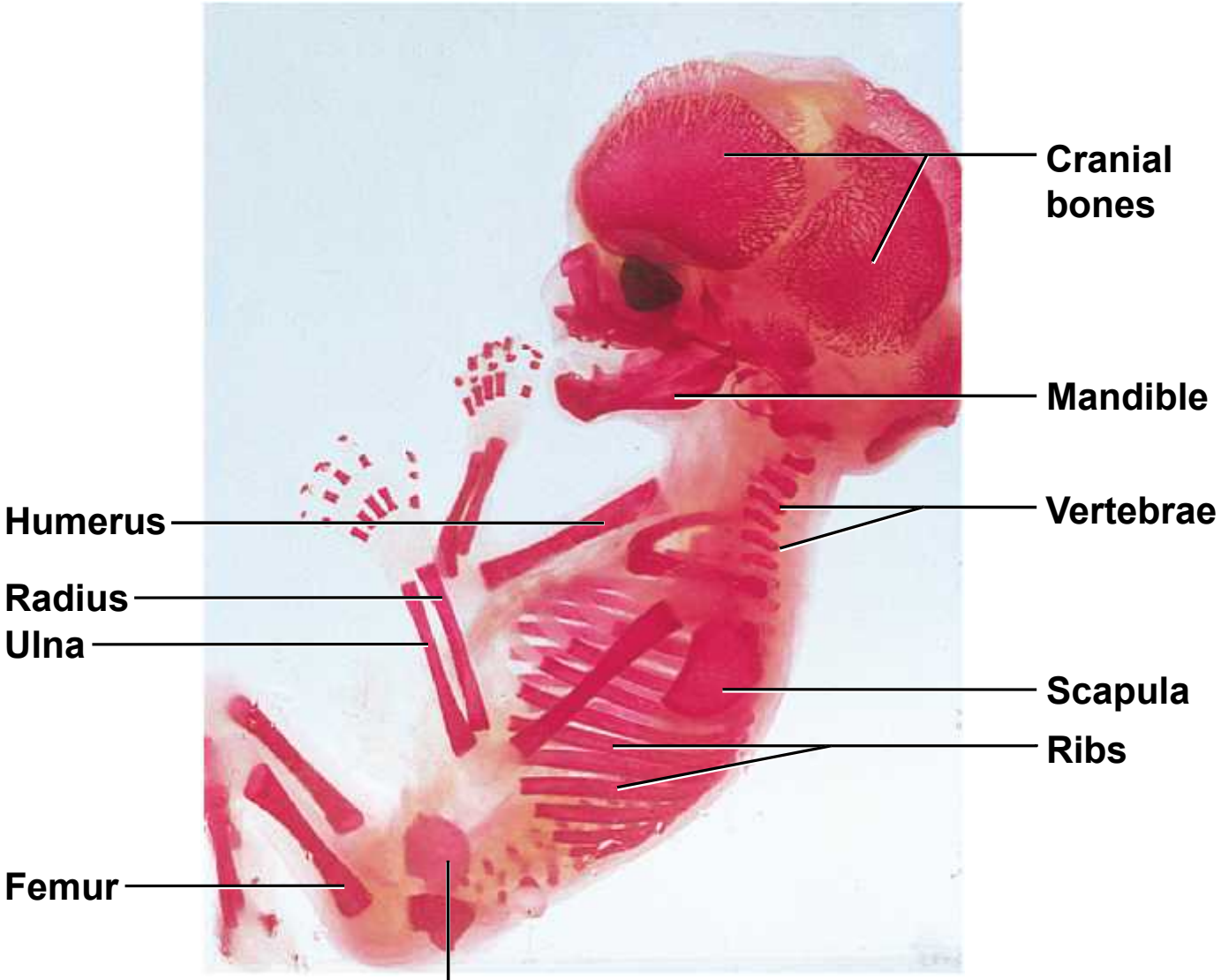


Figure 7.10

Bone Growth and Remodeling

- **Ossification** continues throughout life with the growth and remodeling of bones
- Bones grow in two directions
  - **Length**
  - **Width**

Bone Elongation

- **Epiphyseal plate**—a region of transition from cartilage to bone
  - Functions as **growth zone** where the bones elongate
  - Consists of typical hyaline cartilage in the middle
  - With a transition zone on each side where cartilage is being replaced by bone
  - **Metaphysis** is the zone of transition facing the marrow cavity

X-Ray of Child's Hand

Epiphyseal Plates

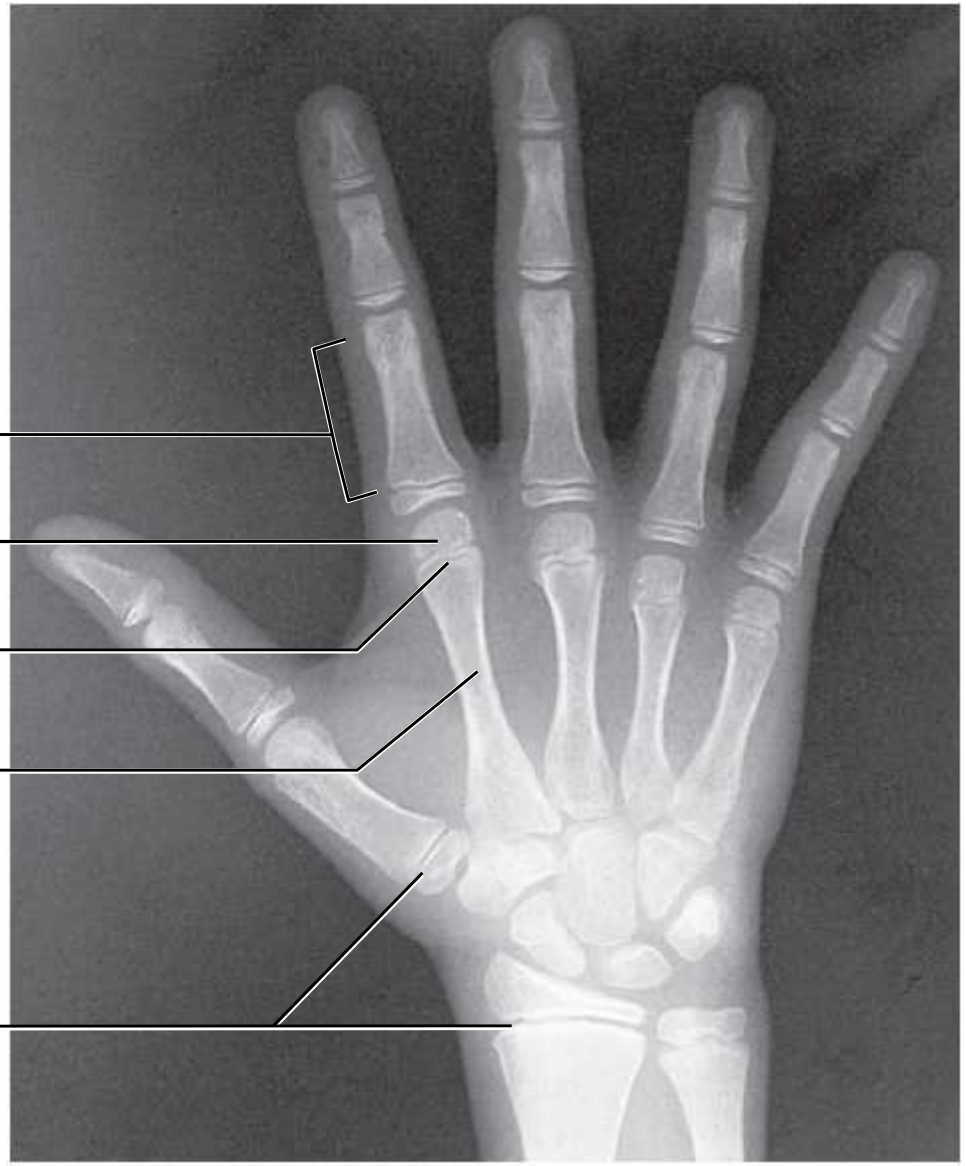
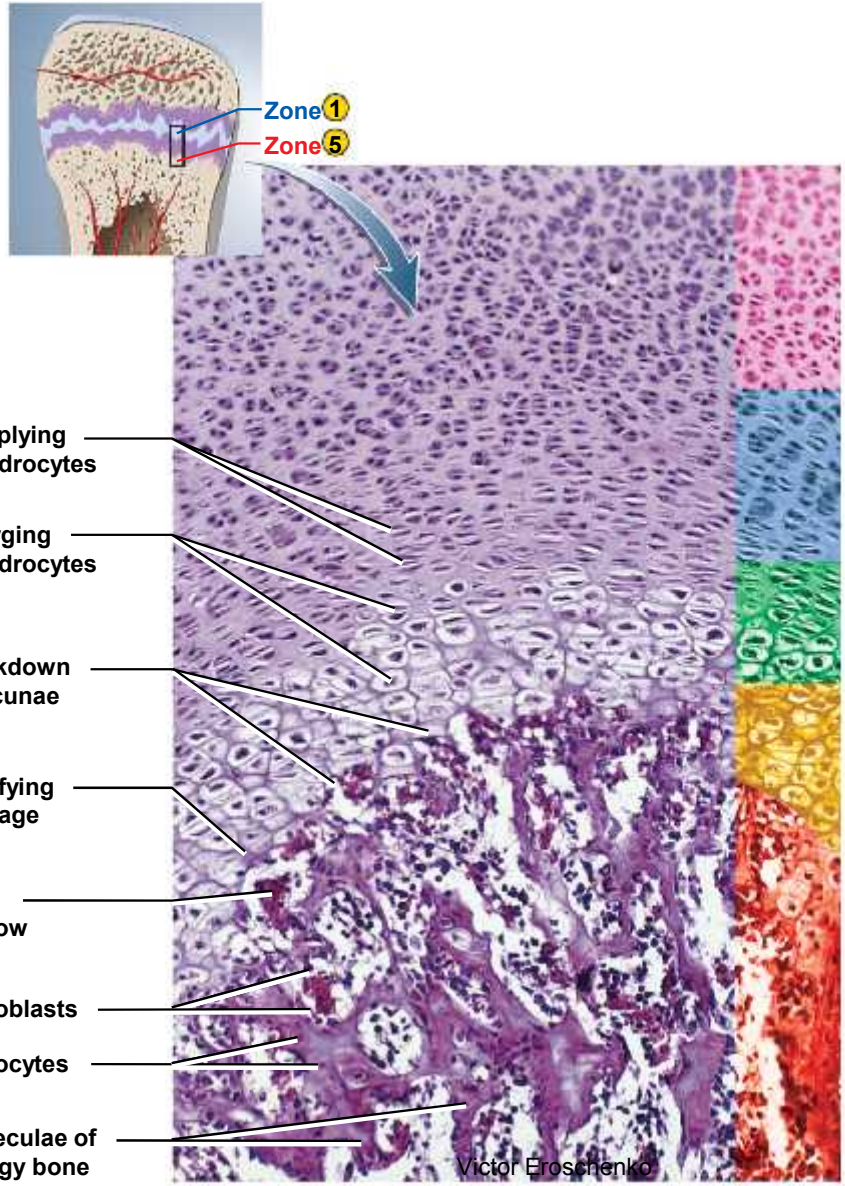


Figure 7.11

Courtesy of Utah Valley Regional Medical Center, Department of Radiology

Zones of the Metaphysis



1. **Zone of reserve cartilage**
   Typical histology of resting hyaline cartilage
2. **Zone of cell proliferation**
   Chondrocytes multiplying and lining up in rows of small flattened lacunae
3. **Zone of cell hypertrophy**
   Cessation of mitosis; enlargement of chondrocytes and thinning of lacuna walls
4. **Zone of calcification**
   Temporary calcification of cartilage matrix between columns of lacunae
5. **Zone of bone deposition**
   Breakdown of lacuna walls, leaving open channels; death of chondrocytes; bone deposition by osteoblasts, forming trabeculae of spongy bone

Figure 7.12

Bone Widening and Thickening

- **Interstitial growth**—bones increase in length
  - Bone elongation is really a result of cartilage growth within the epiphyseal plate
  - Epiphyses close when cartilage is gone—**epiphyseal line**
  - Lengthwise growth is finished
    - Occurs at different ages in different bones

Bone Widening and Thickening

- **Appositional growth—**bones increase in width throughout life
  - Deposition of new bone at the surface
  - Osteoblasts on deep side of periosteum deposit osteoid tissue
    - Become trapped as tissue calcifies
  - Lay down matrix in layers parallel to surface
    - Forms **circumferential lamellae** over surface
      - Osteoclasts of endosteum enlarge marrow cavity

Bone Remodeling

- **Bone remodeling** occurs throughout life—10% per year
  - Repairs microfractures, releases minerals into blood, reshapes bones in response to use and disuse
  - **Wolff's law of bone:** architecture of bone determined by mechanical stresses placed on it and bones adapt to withstand those stresses
    - Remodeling is a collaborative and precise action of osteoblasts and osteoclasts
    - Bony processes grow larger in response to mechanical stress

Dwarfism

Figure 7.13

- **Achondroplastic dwarfism**
  - Long bones stop growing in childhood
    - Normal torso, short limbs
  - Failure of cartilage growth in metaphysis
  - Spontaneous mutation produces mutant dominant allele
- **Pituitary dwarfism**
  - Lack of growth hormone
  - Normal proportions with short stature

Physiology of Osseous Tissue

- **Expected Learning Outcome**
  - Describe the processes by which minerals are added to and removed from bone tissue.
  - Describe the role of the bones in regulating blood calcium and phosphate levels.
  - Name several hormones that regulate bone physiology and describe their effects.

Physiology of Osseous Tissue

- **A mature bone remains a metabolically active organ**
  - Involved in its own maintenance of growth and remodeling
  - Exerts a profound influence over the rest of the body by exchanging minerals with tissue fluid
    - Disturbance of **calcium homeostasis** in skeleton disrupts function of other organ systems
      - Especially nervous and muscular

Mineral Deposition and Resorption

- **Mineral deposition (mineralization)**—crystallization process in which calcium phosphate and other ions are taken from the blood plasma and deposited in bone tissue
  - **Osteoblasts** produce collagen fibers that spiral the length of the osteon
  - Fibers become encrusted with minerals that harden the matrix
    - Calcium and phosphate (hydroxyapatite) from blood plasma are deposited along the fibers

Mineral Deposition and Resorption

Cont.

- Calcium and phosphate ion concentration must reach a critical value called the **solubility product** for crystal formation to occur
- Most tissues have **inhibitors** to prevent this so they do not become calcified
- Osteoblasts **neutralize these inhibitors** and allow salts to precipitate in the bone matrix
- First few crystals (**seed crystals**) attract more calcium and phosphate from solution

Mineral Deposition and Resorption

- **Abnormal calcification (ectopic ossification)**
  - May occur in lungs, brain, eyes, muscles, tendons, or arteries (arteriosclerosis)
  - **Calculus:** calcified mass in an otherwise soft organ such as the lung
- **Mineral resorption**—the process of dissolving bone and releasing minerals into the blood
  - Performed by **osteoclasts** at the **ruffled border**
  - **Hydrogen pumps** in membranes secrete hydrogen into space between the osteoclast and bone surface

Mineral Deposition and Resorption

Cont.

- **Chloride ions** follow by electrical attraction
- **Hydrochloric acid** (pH 4) dissolves bone minerals
- **Acid phosphatase** enzyme digests the collagen

- **Orthodontic appliances** (braces) reposition teeth
  - Tooth moves because **osteoclasts** dissolve bone ahead of the tooth, where the pressure on the bone is the greatest
  - **Osteoblasts** deposit bone more slowly in the low-pressure zone behind the tooth

Calcium Homeostasis

- Calcium and phosphate are used for much more than bone structure
- Phosphate is a component of DNA, RNA, ATP, phospholipids, and pH buffers
- Calcium needed in neuron communication, muscle contraction, blood clotting, and exocytosis
- Minerals are deposited in the skeleton and withdrawn when they are needed for other purposes

Calcium Homeostasis

- About 1,100 g calcium in adult body
  - 99% in the skeleton
    - As easily exchangeable calcium ions and more stable hydroxyapatite reserve
    - 18% of adult skeleton exchanged with blood each year
- Normal calcium concentration in blood plasma is **9.2 to 10.4 mg/dL**—45% as Ca^{2+} can diffuse across capillary walls and affect other tissues; rest in reserve, bound to plasma proteins

Calcium Homeostasis

- **Hypocalcemia** has a wide variety of causes, blood calcium excess
  - Vitamin D deficiency
  - Diarrhea
  - Thyroid tumors
  - Underactive parathyroids
  - Pregnancy and lactation
  - Accidental removal of parathyroid glands during thyroid surgery

Calcium Homeostasis

- **Calcium homeostasis** depends on a balance between dietary intake, urinary and fecal losses, and exchanges between osseous tissue
- Calcium homeostasis is regulated by three hormones:
  - **Calcitriol, calcitonin,** and **parathyroid hormone**

Calcitriol Synthesis and Action

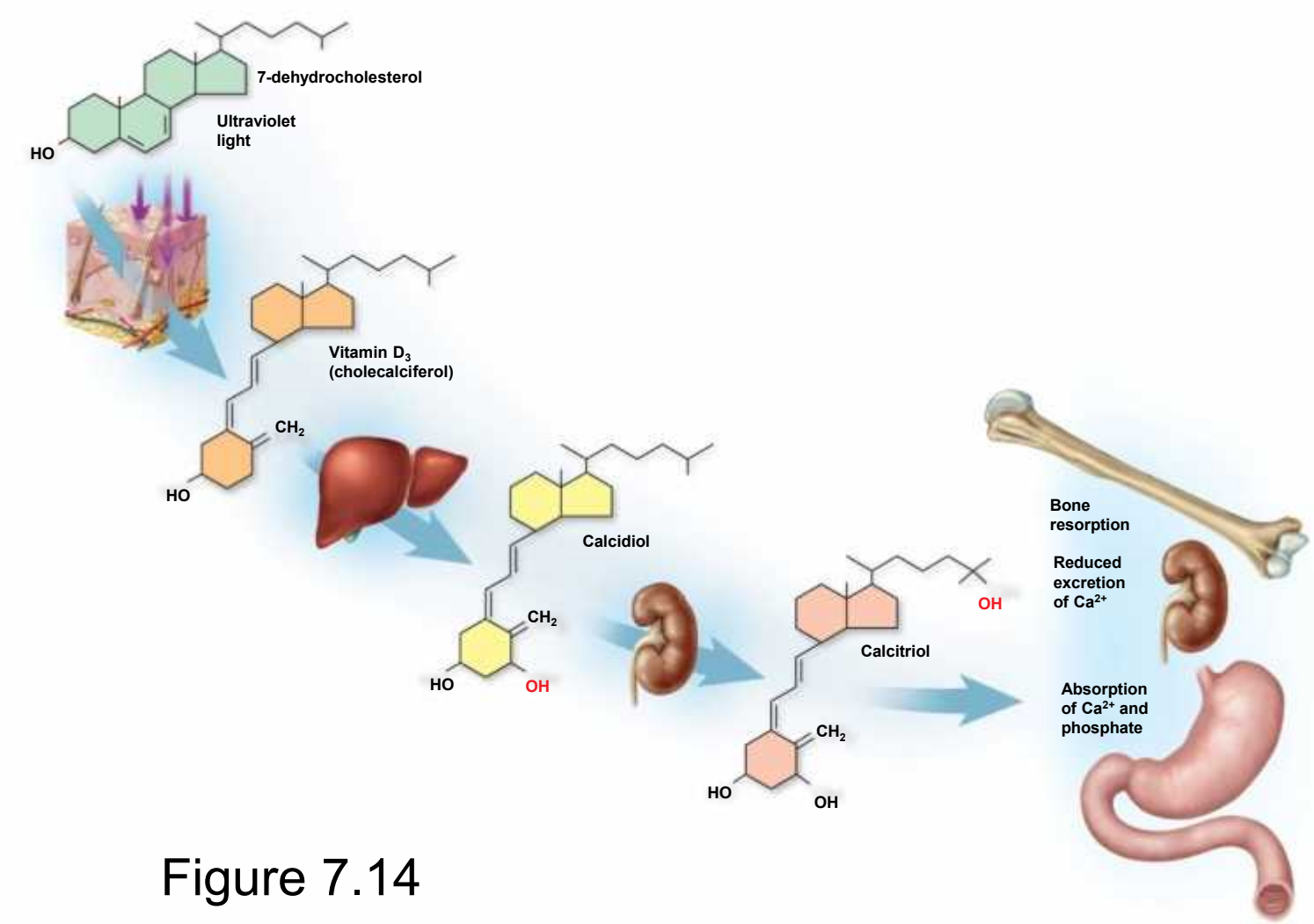


Figure 7.14

Calcitriol

- **Calcitriol**—a form of vitamin D produced by the sequential action of the skin, liver, and kidneys
- Produced by the following process
  - **Epidermal keratinocytes** use UV radiation to convert a steroid, **7-dehydrocholesterol** to **previtamin D_3**
  - **Liver** adds a hydroxyl group converting it to **calcidiol**
  - **Kidneys** add another hydroxyl group, converting that to **calcitriol**

    (most active form of vitamin D); also from fortified milk

Calcitriol

Cont.

- Calcitriol behaves as a **hormone** that **raises blood calcium concentration**
  - Increases calcium absorption by small intestine
  - Increases calcium resorption from the skeleton
  - Promotes kidney reabsorption of calcium ions, so less lost in urine
- Necessary for bone deposition—need adequate calcium and phosphate
- Abnormal softness of bones in children (**rickets**) and in adults (**osteomalacia**) without adequate vitamin D

Calcium Homeostasis

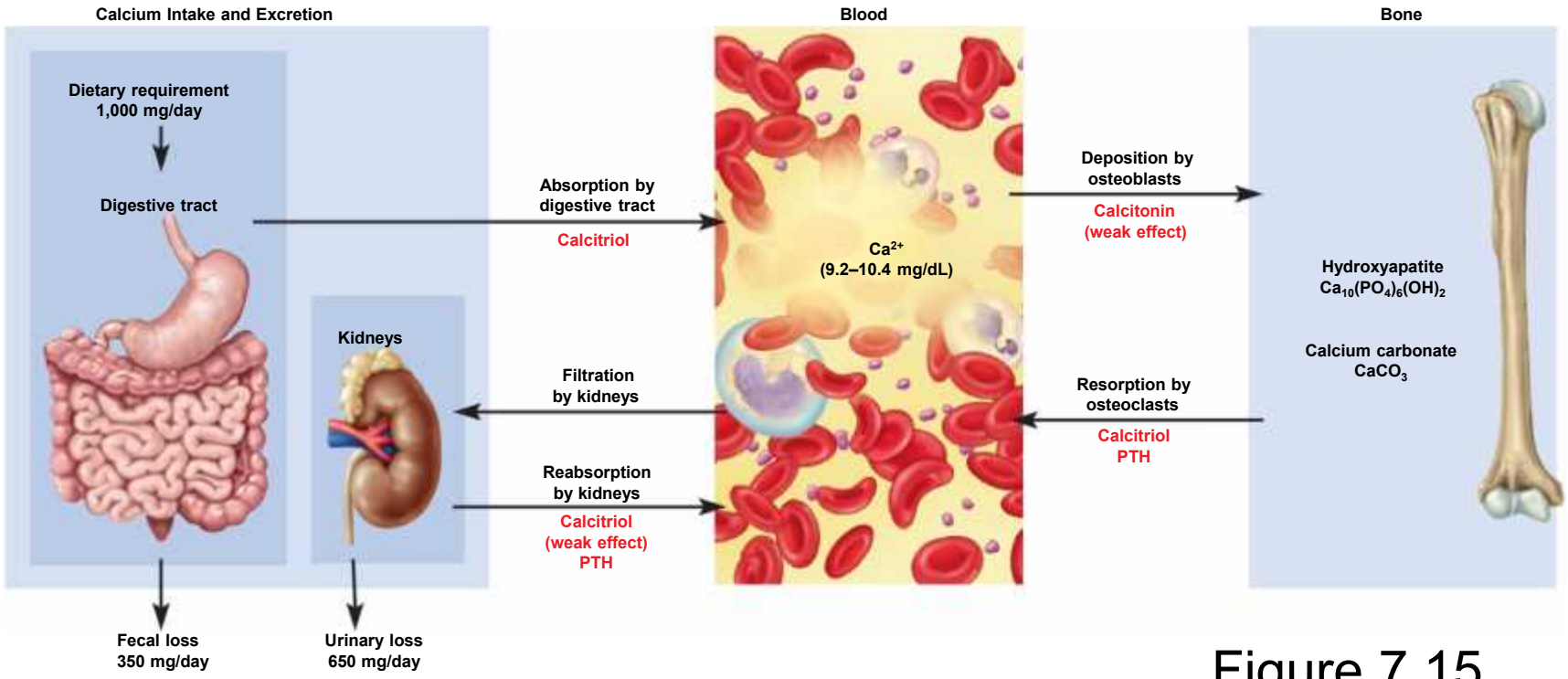


Figure 7.15

Calcitriol, calcitonin, and PTH maintain normal blood calcium concentration

Calcitonin

- **Calcitonin**—secreted by **C cells (clear cells)** of the **thyroid gland** when calcium concentration rises **too high**
- **Lowers blood calcium concentration** in two ways
  - **Osteoclast inhibition**
    - Reduces osteoclast activity as much as 70%
    - Less calcium liberated from bones
  - **Osteoblast stimulation**
    - Increases the number and activity of osteoblasts
    - Deposits calcium into the skeleton

Calcitonin

- Important in children, weak effect in adults
  - Osteoclasts more active in children due to faster remodeling
  - Deficiency does not cause disease in adults
- Reduces bone loss in women during pregnancy and lactation

Parathyroid Hormone

- **Parathyroid hormone (PTH)**—secreted by the parathyroid glands which adhere to the posterior surface of thyroid gland
- PTH released with low calcium blood levels
- **PTH raises calcium blood level** by four mechanisms
  - Binds to receptors on osteoblasts
    - Simulating them to secrete RANKL which raises the osteoclast population

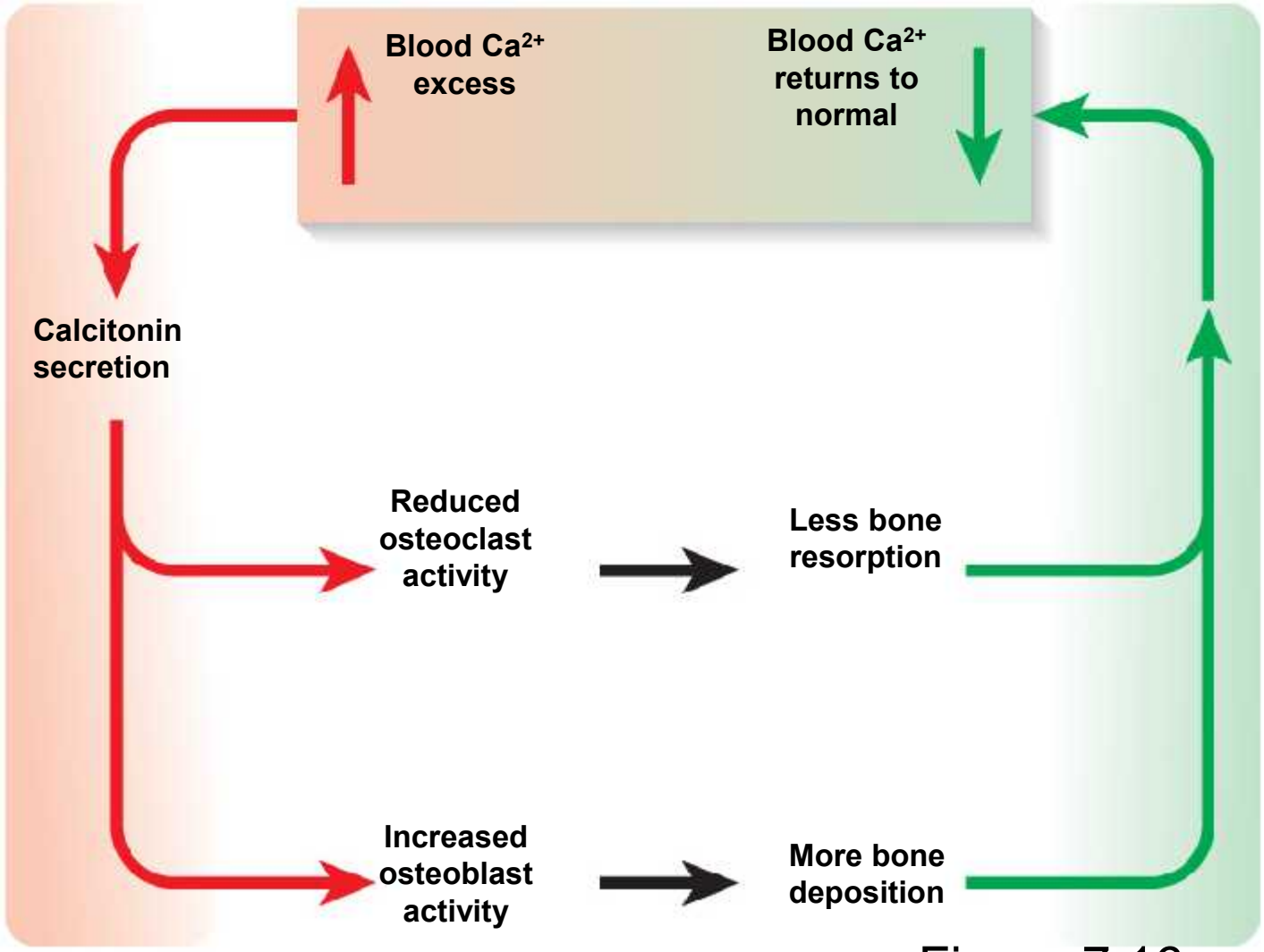
Parathyroid Hormone

Cont.

- Promotes calcium reabsorption by the kidneys, less lost in urine
- Promotes the final step of calcitriol synthesis in the kidneys, enhancing calcium-raising effect of calcitriol
- Inhibits collagen synthesis by osteoblasts, inhibiting bone deposition

- Sporadic injection or secretion of low levels of PTH causes bone deposition, and can increase bone mass

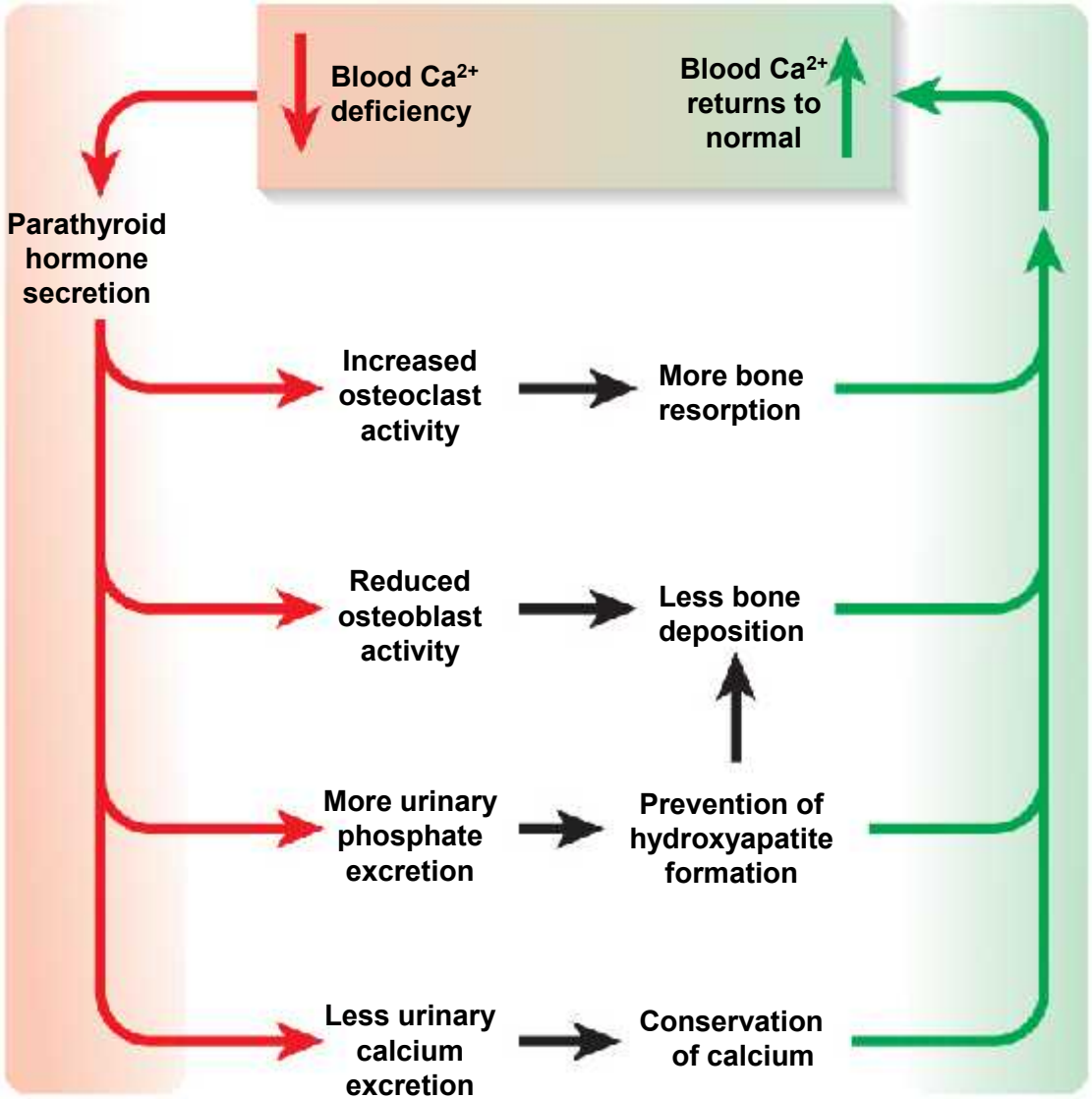
Calcium Homeostasis



(a) Correction for hypercalcemia

Figure 7.16a

Calcium Homeostasis



(b) Correction for hypocalcemia

Figure 7.16b

Phosphate Homeostasis

- Average adult has 500 to 800 g phosphorus
- 85% to 90% of phosphate is in the bones
- Normal plasma concentration is **3.5 to 4.0 mg/dL**
- Occurs in **two principal forms**
  - **HPO_4^{2-}** and **$H_2PO_4^-$** (monohydrogen and dihydrogen phosphate ions)

Phosphate Homeostasis

- Phosphate levels are not regulated as tightly as calcium levels
  - No immediate functional disorders
- Calcitriol promotes its absorption by small intestine and promotes bone deposition
- PTH lowers blood phosphate level by promoting its urinary excretion

Other Factors Affecting Bone

- At least 20 or more hormones, vitamins, and growth factors affect osseous tissue
- Bone growth especially rapid in puberty and adolescence
  - Surges of growth hormone, estrogen, and testosterone occur and promote ossification
  - These hormones stimulate multiplication of osteogenic cells, matrix deposition by osteoblasts, and chondrocyte multiplication and hypertrophy in metaphyses

Other Factors Affecting Bone

Cont.

- Girls grow faster than boys and reach full height earlier
  - Estrogen stronger effect than testosterone on bone growth
- Males grow for a longer time and taller

- **Anabolic steroids** cause growth to stop
  - Epiphyseal plate “closes” prematurely
  - Results in abnormally short adult stature

Bone Disorders

- **Expected Learning Outcomes**
  - Name and describe several bone diseases.
  - Name and describe the types of fractures.
  - Explain how a fracture is repaired.
  - Discuss some clinical treatments for fractures and other skeletal disorders.

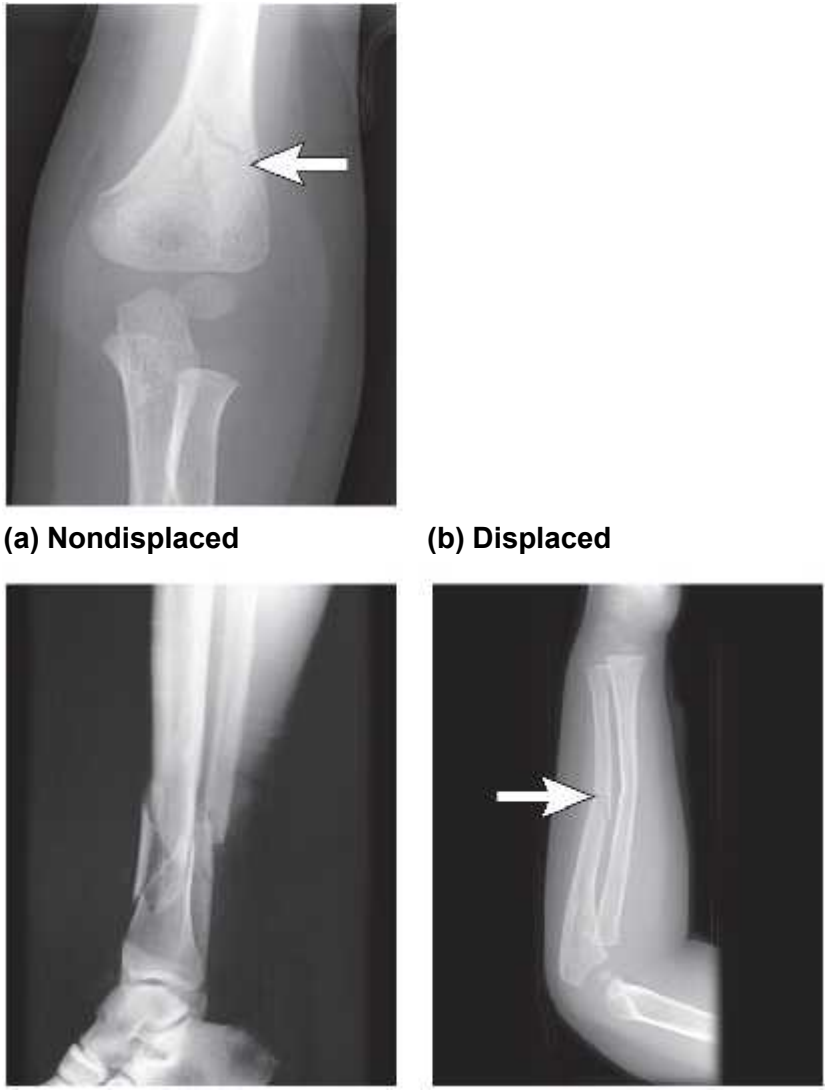
Bone Disorders

- Orthopedics—originated as the name implies, as the treatment of skeletal deformities in children
- Deals with the prevention and correction of injuries and disorders of bones, joints, and muscles
- Includes the design of artificial joints and limbs and the treatment of athletic injuries

Fractures and Their Repair

- **Stress fracture**—break caused by abnormal trauma to a bone
  - Falls, athletics, and military combat
- **Pathological fracture**—break in a bone weakened by some other disease
  - Bone cancer or osteoporosis
  - Usually caused by stress that would not break a healthy bone
- **Fractures** classified by structural characteristics
  - Direction of fracture line
  - Break in the skin
  - Multiple pieces

Types of Bone Fractures



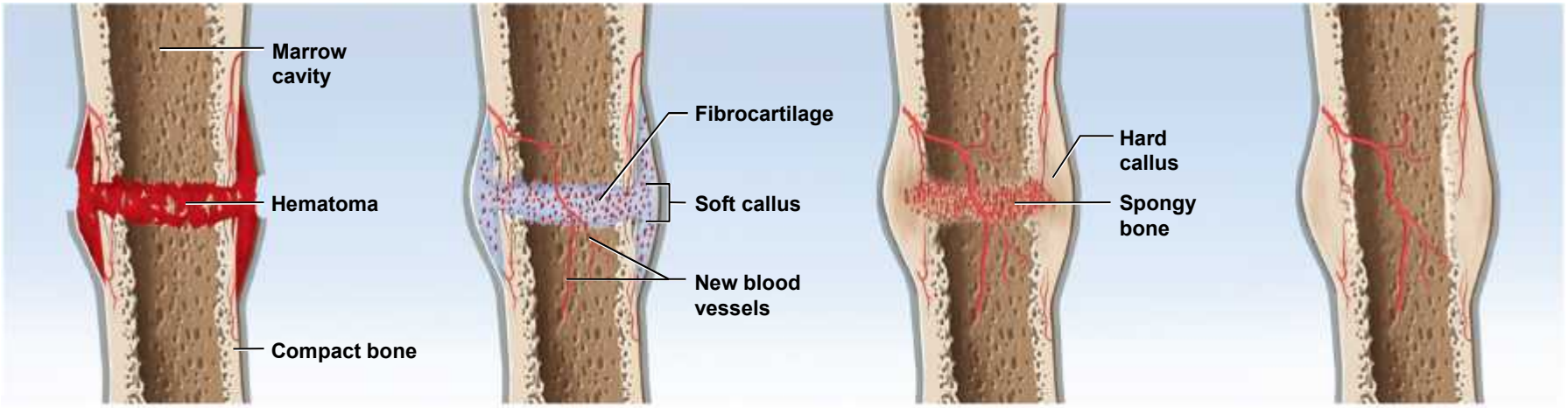
(a) Nondisplaced **(b) Displaced**

(c) Comminuted **(d) Greenstick**

Figure 7.17

a: Custom Medical Stock Photo, Inc.; c: © Lester V. Bergman/Corbis; d: Custom Medical Stock Photo, Inc.

Healing of Fractures



1. **Hematoma formation** The hematoma is converted to granulation tissue by invasion of cells and blood capillaries.
2. **Soft callus formation** Deposition of collagen and fibrocartilage converts granulation tissue to a soft callus.
3. **Hard callus formation** Osteoblasts deposit a temporary bony collar around the fracture to unite the broken pieces while ossification occurs.
4. **Bone remodeling** Small bone fragments are removed by osteoclasts, while osteoblasts deposit spongy bone and then convert it to compact bone.

Figure 7.18

The Treatment of Fractures

- **Closed reduction**—procedure in which the bone fragments are manipulated into their normal positions without surgery
- **Open reduction**—involves surgical exposure of the bone and the use of plates, screws, or pins to realign the fragments
- **Cast**—normally used to stabilize and immobilize healing bone

The Treatment of Fractures

- **Traction**—used to treat fractures of the femur in children
  - Aligns bone fragments by overriding force of the strong thigh muscles
  - Risks long-term confinement to bed
  - Rarely used for the elderly
  - Hip fractures are usually pinned in elderly and early **ambulation** (walking) is encouraged to promote blood circulation and healing
- **Electrical stimulation** accelerates repair
  - Suppresses effects of parathyroid hormone
- **Orthopedics**—branch of medicine that deals with prevention and correction of injuries and disorders of the bones, joints, and muscles

Open Reduction of an Ankle Fracture

Figure 7.19

Other Bone Disorders

- **Osteoporosis**—the most common bone disease
  - Severe loss of bone density
- Bones lose mass and become brittle due to loss of organic matrix and minerals
  - Affects spongy bone the most since it is the most metabolically active
  - Subject to pathological fractures of hip, wrist, and vertebral column
  - **Kyphosis (widow's hump)**—deformity of spine due to vertebral bone loss
  - Complications of loss of mobility are pneumonia and thrombosis

Osteoporosis

- Estrogen maintains density in both sexes; inhibits resorption by osteoclasts
  - Testes and adrenals produce estrogen in men
  - In women, rapid bone loss after menopause since ovaries cease to secrete estrogen
- Osteoporosis is common in young female athletes with low body fat causing them to stop ovulating and ovarian estrogen secretion is low

Osteoporosis

Cont.

- Treatments
  - **Estrogen replacement therapy (ERT)** slows bone resorption, but increases risk of breast cancer, stroke, and heart disease
  - Drugs **Fosamax, Actonel** destroy osteoclasts
  - **PTH** slows bone loss if given as daily injection
    - **Forteo** (PTH derivative) increases density by 10% in 1 year
      - May promote bone cancer so use is limited to 2 years
  - Best treatment is **prevention:** exercise and a good bone-building diet between ages 25 and 40

Other Bone Disorders

- Postmenopausal white women at greatest risk
  - Begin to lose bone mass as early as age 35
    - By age 70, average loss is 30% of bone mass
  - Risk factors: race, age, gender, smoking, diabetes mellitus, diets poor in calcium, protein, vitamins C and D

Spinal Osteoporosis

(a) (b)

a: © Michael Klein/Peter Arnold, Inc.; b: © Dr. P. Marzzi/Photo Researchers, Inc.

Figure 7.20a,b