The Skeletal System
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OUTLINE:

- Bone Functions
- Bone Structure
- Bone as a Living Tissue
- The Role of Fibroblasts and Osteoblasts in Repairing Bone Fractures
- Bone Remodeling
- Axial Skeleton
- Appendicular Skeleton
- Joints
Bone Functions

- The skeleton is a framework of bones and cartilage that performs several functions
  - Support for soft tissues
  - Provides a place of attachment for muscles
  - Protects internal organs
  - Stores minerals and fat
  - Certain bones produce blood cells in the red marrow
Bone Structure

- The human body has 206 bones that vary in size and shape.

- Most bones contain both *compact* and *spongy* bones in proportions that depend on the bone’s size and shape.
Bone Structure

- Compact bone
  - Dense outer layer with few internal spaces
  - Forms most of the shaft of long bones (arms, legs)
  - Covered by the periosteum that nourishes the bones
    - Contains blood vessels, nerves, and cells involved in bone growth and repair
    - Injury to the periosteum (bruise, fracture) generates pain
Bone Structure

- Spongy bone
  - Latticework of bone
  - Found in small, flat bones (skull) and in the head and near the ends of the shafts of long bones
  - In adults
    - The spaces of some spongy bones are filled with red marrow where blood cells form
    - The cavity in the shaft of long bones is filled with yellow marrow, a fatty tissue for energy storage
Figure 5.1 The structure of bone.

(a) A long bone, such as the femur of the leg, consists of a shaft and two heads, or enlarged ends. Compact bone is located on the outer surface of the bone. Spongy bone is found in the heads.

(b) The structural unit of compact bone is an osteon. Mature, living bone cells (osteocytes) are found in small spaces within the hard matrix.

(c) A light micrograph of compact bone showing an osteon.

(d) Bone cells extend outward through tiny canals and touch one another. In this way, materials can be exchanged with the blood supply in the central canal.

(e) The internal struts of spongy bone support the bone from within.
Bone as a Living Tissue

- The structural unit of compact bones is called an **osteon**
  - Consists of osteocytes (living bone cells) arranged in concentric rings around a central canal
  - Each osteocyte lies within a lacuna (small space within the hard matrix)
  - Tiny canals connect nearby lacunae and the central canal
  - Nutrients, oxygen, and wastes pass from cell to cell, traveling to and from the blood vessels in the central canal
Bone as a Living Tissue

- Bone is a living tissue, but its most noticeable characteristics result from its nonliving component: the solid matrix
  - Hard due to calcium and phosphorus salts
  - Resilient due to strands of the elastic protein collagen
Cartilage Model

- During embryonic development, most of the skeleton is first formed of cartilage.
- Cartilage cells are capable of dividing (mitosis), unlike mature bone cells, which are enclosed in a solid matrix.
- The cartilage model can grow as rapidly as the fetus does.
- Beginning at the third month and through prenatal development, the cartilage is gradually replaced by bone.
Figure 5.2 *The fetal skeleton is first made of cartilage and gradually is replaced by bone.*
Cartilage Model

- The transformation from cartilage to a long bone
  - Begins when osteoblasts form a collar of bone around the shaft of the cartilage model
  - Osteoblasts then migrate to the bone cavity to form spongy bone
  - Cartilage cells within the growth plate divide, forcing the end of the bone farther away from the shaft
  - As bone replaces the newly formed cartilage in the region closer to the shaft, the bone lengthens
  - The bone diameter also enlarges as the bone lengthens
Two regions of cartilage remain at each end of the long bone

- The cap that covers the surfaces that rub against other bones
- The growth plate, also called the epiphyseal plate
Bone Growth

Bone formation begins early in development and continues from the fetal to early childhood stages. It involves the formation of a cartilaginous shaft around the osteoblasts, which form a collar that ultimately forms bone tissue.

Press "PLAY" to begin Animation.
Figure 5.3 Steps of bone formation in long and short bones, from an embryo into childhood.

**Fetal Development**
- **2 months**: Cartilaginous model, Bone collar
- **3 months**: Deteriorating cartilage matrix
- **9 months**: Calcified cartilage, Blood vessel

**Birth**
- Spongy bone formation
- Cartilaginous (epiphyseal) growth plate

**Childhood**
- Cartilaginous surface, Spongy bone
- Compact bone

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**Step 1:** A cartilaginous model of the future bone forms.

**Step 2:** Osteoblasts form a collar of bone around the shaft of the model.

**Step 3:** The shaft of the cartilage model begins to hollow out, and spongy bone fills the space. Blood vessels continue to penetrate the area, and the region of bone formation expands.

**Step 4:** Secondary centers of bone formation develop in the ends of the bone.

**Step 5:** Cartilage remains only on the surfaces that rub against other bones and in the cartilage growth plates.
Hormones and Bone Growth

- Growth hormone stimulates bone growth during childhood
- Thyroid hormones ensure that the skeleton grows with the proper proportions
- Sex hormones (testosterone and estrogen) prompt and stop the growth spurt of puberty
Hormones and Bone Growth

- By the end of the teenage years, sex hormones initiate less frequent cell division
  - Growth plate thins
  - Ends of the bone fuse with the shaft
  - Bone can no longer increase in length
The Role of Fibroblasts and Osteoblasts in Repairing Bone Fractures

- Nondisplaced fracture: the ends remain aligned
- Displaced fracture: the ends must be realigned
- When a bone breaks, bleeding occurs and a clot forms
- Fibroblasts invade the clot and secrete collagen fibers that form a callus linking the two parts of the bone
- Osteoblasts transform this cartilage into bone
The Role of Fibroblasts and Osteoblasts in Repairing Bone Fractures

Bone Repair

Bone repair begins with the formation of a hematoma in the region of damage. Fibroblasts form a cartilaginous callus, which is converted into a bony callus by osteoblasts. This process involves formation of new blood vessels and bone remodeling before healing occurs.

Press "PLAY" to begin Animation.
Figure 5.5 The progress of healing in a bone.

**Step 1**: Within hours after the fracture, a blood clot forms.

**Step 2**: A cartilaginous callus is formed by invading fibroblasts.

**Step 3**: Osteoblasts form new bone, converting the cartilaginous callus to a bony callus.

**Step 4**: The fracture is healed and bone is remodeled, restoring bone to original shape.
Bone Remodeling

- Bones continually undergo remodeling
  - New bone is deposited by osteoblasts
  - Old bone is broken down by osteoclasts
- Bone remodeling repairs tiny cracks and regulates blood calcium levels
- Two antagonistic hormones are involved
  - Calcitonin released from the thyroid gland decreases blood calcium levels
  - Parathyroid hormone (PTH) released from the parathyroid glands increases blood calcium levels
Bone Remodeling

- In women, estrogen also plays a role in bone remodeling
  - Enhances the absorption of calcium from the digestive system
  - Stimulates the formation of bone
  - Inhibits the breakdown of bone
- Osteoporosis results when bone is broken down faster than it is deposited
Bone Remodeling

- Bone tissue forms in response to stress on the bone
- Bone tissue is absorbed in the absence of stress on the bone
Axial Skeleton

- The bones of the human body can be divided into two groups
  - Axial skeleton
  - Appendicular skeleton
Figure 5.6 Major bones of the human body. Bones of the axial skeleton are shown in orange; bones of the appendicular skeleton are shown in light brown. Cartilage is shown in light purple.
Axial Skeleton

- The axial skeleton: protects and supports our internal organs

  - Components
    - Skull
    - Vertebral column
    - Sternum and rib cage
Skull

- The most complex bony structure in the body
  - Two divisions: cranium and face
Figure 5.7 **Major bones of the skull and face.**

(a) Left side of skull

(b) Lower surface of skull

(c) Front view of skull showing facial bones
Cranial and Facial Bones

- Cranial bones:
- The cranium which is formed from eight (sometimes more) flat bones
  - Protect the brain
  - House the structures of hearing
  - Provide attachment sites for the muscles of the head and neck
- Facial bones (fourteen bones)
  - Support several sensory structures
  - Serve as attachment sites for most facial muscles
Cranial and Facial Bones

- Before and shortly after birth, the bones of the cranium are connected by membranous areas called fontanels
  - Allow the skull to be compressed during birth as the baby passes through the birth canal
  - Allow for the rapid growth of the brain during the fetal period and infancy
  - Replaced by bone by 2 years of age
Figure 5.8 *The skull bones of a human newborn are not fused but are instead connected by fibrous connective tissue.*
Vertebral Column

- The vertebral column consists of 26 vertebrae
  - 7 cervical (neck) vertebrae (C1–C7)
  - 12 thoracic (chest) vertebrae (T1–T12)
  - 5 lumbar (lower back) vertebrae (L1–L5)
  - 1 sacrum (formed by the fusion of five sacral vertebrae)
  - 1 coccyx (or tailbone, formed by fusion of four vertebrae)
Vertebral Column

- Intervertebral disks separate vertebrae from one another
  - Pads of fibrocartilage
  - Become compressed over the years and individuals become shorter as they age
Figure 5.9 A side view of the vertebral column.
Vertebral Column and Scoliosis

- Scoliosis
  - “Twisted disease”
  - Abnormal curvature of the spine
  - Cause is unknown
  - Affects over 1.5 million adolescents, primarily females
  - Treatment may involve a brace or surgery
The term “slipped disk” is a misnomer

- It is a disk that bulges but does not move out of place
- If a disk bulges inward, it can press against the spinal cord and interfere with perception of incoming stimuli and muscle control
- If a disk bulges outward, it can press against the sciatic nerve and cause the painful inflammatory condition sciatica
Rib Cage

- 12 pairs of ribs attach at the back of the rib cage to the thoracic vertebrae
  - Upper 10 pairs are attached by cartilage either directly or indirectly to the sternum
  - Last two pairs do not attach to the sternum and are called “floating ribs"
Figure 5.10 The bones of the rib cage. Cartilage is shown in light purple.
Appendicular Skeleton

- The appendicular skeleton allows movement and interaction with the environment

  - Components
    - Pectoral girdle
    - Pelvic girdle
    - Limbs
Pectoral Girdle

- Composed of:
  - Scapulae
  - Clavicles

- Function:
  - Supports the arms
Figure 5.11 *The pectoral girdle and arm.*

- **Pectoral girdle**
  - **Clavicle** (collarbone)
  - **Scapula** (shoulder blade)

- **Humerus** (upper arm)

- **Forearm**
  - **Ulna**
  - **Radius**

- **8 Carpals** (wrist)
- **5 Metacarpals** (hand)
- **14 Phalanges** (finger bones)
Pelvic Girdle

- More rigid than the pectoral girdle
  - Composed of:
    - Two pelvic bones joined in front at the pubic symphysis
  - Function:
    - Supports the legs
Figure 5.12 *The pelvic girdle and leg.*

- Pelvic bones
- Pelvis
- Pubic symphysis
- Femur (upper leg)
- Patella (kneecap)
- Tibia
- Lower leg
- Fibula
- 7 Tarsals (ankle)
- 5 Metatarsals (foot)
- 14 Phalanges (toe bones)
Joints

- Joints are places where bones meet and are classified as:
  - Fibrous
  - Cartilaginous
  - Synovial
Joints

- Fibrous joints
  - Held together by fibrous connective tissue
  - Have no joint cavity
  - Most do not permit movement
  - Example: the immovable joints between the skull bones in an adult (sutures)
Joints

- Cartilaginous joints
  - Allow very little movement
  - Examples: between vertebrae, also where ribs attach to the sternum and in the pubic symphysis
Synovial Joints

- Synovial joints are freely movable and most joints in the body are of this type
  - The surfaces that move past one another have a thin layer of cartilage
  - A thin capsule containing synovial fluid (a lubricant) surrounds these joints
  - The entire joint is reinforced with ligaments, which are straps of connective tissue that hold bones together and direct movement
Figure 5.13 *The knee is a synovial joint.*

(a) Synovial joints, such as the knee shown here, permit a great range of movement.

(b) Ligaments hold bones together, support the joint, and direct the movement of the bones.
Synovial Joints

- Synovial joints differ in the type and range of motion they permit
  - Hinge joints
    - Motion in only one plane
    - Example: knee
  - Ball-and-socket joints
    - Motion in all planes
    - Example: shoulder
Figure 5.14 Types of movement at synovial joints.

- **Flexion**: Motion that decreases the angle between the bones of the joint, bringing the bones closer together.

- **Extension**: Motion that increases the angle between the bones of the joint.

- **Adduction**: Movement of a body part toward the body midline.

- **Abduction**: Movement of a body part away from the body midline.

- **Rotation**: Movement of a body part around its own axis.

- **Circumduction**: Movement of a body part in a wide circle so that the motion describes a cone.

- **Supination**: Rotation of the forearm so that the palm faces up.

- **Pronation**: Rotation of the forearm so that the palm faces down.
Damage to Joints

- **Sprains**
  - Injuries to ligaments
  - Range from slight (caused by overstretching) to serious (caused by tearing)
  - Example: tearing the anterior cruciate ligament of the knee

- **Bursitis**
  - Inflammation of the bursae (fluid-filled sacs that surround and cushion joints)
  - Example: inflammation at the elbow from repeatedly swinging a tennis racket
Arthritis

- Joint inflammation
  - Types
    - Osteoarthritis
      - Degeneration of joint surfaces over time
    - Rheumatoid
      - Autoimmune condition marked by an inflammation of the synovial membrane
      - Damaged joint may need to be replaced with an artificial joint
You Should Now Be Able To:

- Describe bone structures and functions
- Understand why bone is a living tissue
- Describe the role of fibroblasts and osteoblasts in repairing bone fractures
- Understand bone remodeling
- Describe the axial skeleton with the main bones involved
- Describe the appendicular skeleton and list the bones present
- Know the types of joints and understand what happens during joint damage