The Skeletal System

Bone Tissue (Osseous Tissue)

Osteocytes [osteo = bone; cyte = cell] – individual bones cells

a. **Osteoclasts [clast=break]** bone cells that produce substances to break down bone tissue, thus removing unneeded tissue, and more importantly, releasing stored minerals like calcium and phosphate.
b. **Osteoblasts [blast = generative] bone cells** that build up or repair bone tissue, thus storing important minerals for future use.

Bone Shapes

a. **Long bones** – bones that are longer than they are wide; act as levers; examples include the humerus, radius, ulna, femur, tibia, fibula, metacarpals, and phalanges.
b. **Short bones** – square or cube-shaped bones; examples include the tarsals and the carpals.
c. **Flat bones** – bones with broad surfaces for muscle attachment; examples include the cranial bones, scapula, ribs, and ilium.
d. **Irregular bones** – bones with varied shapes; examples include the vertebrae and some facial and cranial bones.
e. **Sesamoid bones**-embedded in tendons and joint capsules e.g. patella.

Bone structure

a. **Diaphysis** – shaft of a long bone
b. **Epiphyses** – the ends of a long bone
    i. Epiphyseal plate – the growth plate, the area of the epiphysis where mitotic division of the bones cells takes place allowing the shaft to increase in length.
c. **Articular cartilage** – layer of hyaline cartilage that lines the surfaces of bones where they connect to other bones
d. Medullary cavity – the cavity in the diaphysis of long bones
e. **Periosteum** – a layer of tissue that covers the surfaces of bones; provides a connective layer around the bone to which tendons can attach
    i. Sharpey's fibers – small fibers that connect the periosteum to the surface of the bone.
f. **Compact bone** – the dense outer layer of bone; makes up the shafts of long bones and the outer layer of other bones.
g. **Spongy bone** – bone tissue that contains many porous spaces, causing it to look spongy; found in the epiphyses of long bones and in the interior of other bones.
h. **Bone marrow** – the soft material made up of a meshwork of connective tissue that is found in the cavities of bones

i. Red marrow – tissue found mostly in the spongy bone that produces the blood cells
ii. Yellow marrow – fatty tissue found in the medullary cavity.

Functions of the Bones:

a. Serve as a framework for the body
b. Protect delicate organs such as the brain, spinal cord, lungs, and eyes
c. Serve as levers on which the muscles act to produce body movements
d. Serve as a storehouse for minerals such as calcium and phosphorus
e. Produce red blood cells, white blood cells, and platelets (in the red marrow.)

The Skeleton

Terminology:

Processes – bumps found on the surfaces of bones

1. **Tubercle** – small rounded bump used for muscle attachment
2. **Tuberosity** – large roughened bump
3. **Spine** – a sharp pointed bump
4. **Condyle** – a rounded bump for bone articulation
5. **Epicondyle** – a bump above a condyle
6. **Crest** – a ridge
7. **Line** – a long bump

Depressions and openings –

8. hollow or depressed areas; an orifice or open space
9. **Foramen** – a rounded hole through a bones [plural is foramina]
10. **Fossa** – a shallow depression in a bone
11. **Groove** – a long depression; a furrow in a bone
12. **Sinus** – a cavity in a bone
13. **Meatus** – a canal in a bone
14. **Fissure** – a long, narrow depression in a bone.

Divisions of the skeleton

i. **Axial** – consisting of the bones making up the skull, the spinal column, the ribs and thorax
ii. **Appendicular** – bones making up the appendages of the body

The Joints: Classification of Joints

Articulations

a. **Fibrous joints** – immovable joints; also called **synarthrodial (synarthrosis)** joints' Examples: sutures and epiphyseal (growth) plates
b. **Cartilaginous joints** – slightly movable joints; articulating surfaces of the bones are separated by a piece of cartilage' also called **amphiarthroses**; examples: intervertebral disks and the pubic symphysis
c. **Synovial joints** – freely movable joints; possess a joint cavity encapsulated by ligamentous structures [joint capsule and/or ligaments]; contain synovial fluid that is secreted by the synovial membrane; ends of joints are lined with hyaline cartilage; also called **diarthroses.**
d. Six types of Synovial Joints:
    i. **Hinge joints -** (also called ginglymus – Origin: Gk *gínglymos* hinge) -- joints that act just like a door on hinges; permit movement in only one plane; examples: elbow, knee, and interphalangeal joints.
    ii. **Condylar -** (ellipsoidal) joints – joints formed by convex surface within a concave surface' permit movement in two planes: examples: radiocarpal (wrist) and metacarpophalangeal (base of the fingers) joints.
    iii. **Gliding** - (plane) joints – joints formed by two flat surfaces coming together; allow side-to-side movement, back-and-forth movement and rotation; examples: intercarpal and intertarsal joints, facet joints in the spine.
    iv. **Saddle joints** – joints formed by two saddle-shaped surfaces (convex in one plane, concave in another plane) allow for stabilized movement in two planes; example: carpometacarpal joint in the thumb.
    v. **Ball and Socket joints** – joints formed by a round, convex surface in a socket or cavity; allow movement in all planes (joint with most movement); examples: glenohumeral joint (shoulder) and hip joints.
    vi. **Pivot joints** – joints formed by a cone-shaped surface of one bone articulating with a concave notch of another bone; allow rotation only; examples: atlantoaxial (between c1 and c2), radioulnar joints

Joint Structure

a. **(Synovial Joints):** synovial joints are the most common type of joint in the body and are used to produce most functional movement
b. **Articular cartilage** – lines the contact surfaces of bones within the joint; provides cushion to adjoining bones, congruity of the joint surfaces, and decreased friction in the joint and obtains nutrients by imbibing (absorbing from the synovial fluid within the joint space); when articular cartilage wears thin or becomes inflamed or pathologic, the condition is called arthritis

c. **Joint capsule** – the ligamentous structure that encases and encloses the joint; adds stability to the joint and restricts movement.
d. **Synovial membrane** – lines the inside of the joint capsule; produces synovial fluid.
e. **Synovial fluid** – fluid that fills the joint space; provides nutrition and lubrication to the joint surfaces.
f. **Ligaments** – dense fibrous connective tissue that adds stability to a joint structure; often blends with the joint capsule around the joint; can also be found within the joint cavity.
g. **Bursae** – small, fluid-filled sacs that provide a cushion between bones and tendons and/or muscles around a joint; bursae are filled with synovial fluid and are found around almost every major joint of the body; when they become inflamed, the condition is called bursitis
h. Unique joint structures:
    i. **Meniscus** – a figure eight shaped ring of cartilage found within the knee joint
    ii. **Labrum** – ring of cartilage found within the glenohumeral joint (shoulder)

Joint Movements

a. **Flexion** – a bending movement, decreasing the angle between the anterior surfaces of the bones (except at the knees and toes); examples: bending the elbow, bending the knee, making a fist, bending at the waist to pick something up, pulling the leg up at the hip to step up a stair, bowing the head
b. **Extension** – a straightening movement; increasing the angle between bones to 180 degrees, a return from flexion (i.e. a movement that is opposite of flexion)
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    iii. **Right and left rotation** – rotation of the trunk or neck to the right or left

i. **Circumduction** – a circular or cone-shaped movement involving a combination of flexion, extension, abduction, and adduction; example: drawing a circle on a chalkboard with a straight elbow.
j. **Elevation** – lifting a body part upward: example: shrugging the shoulders, closing the mouth
k. **Depression** – moving a body part downward; example: opening the mouth, pulling the shoulders down from a shrugged position
l. **Dorsiflexion** – pulling the top or dorsal surface of the foot up; ex: pulling the toes upward from ground when standing
m. **Plantar flexion** - pointing the plantar surface of the foot downward: ex: standing on the tips of the toes
n. **Eversion** – rolling the sole of the foot to face more laterally; ex: standing on the inside of the foot
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p. **Protraction** – moving a body part forward; ex: pushing the jaw forward, bringing the head forward, pulling the scapular forward as in a forward reach.
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t. **Lateral flexion** – bending the trunk or neck laterally; also called side bending

Joints of the Body

a. Make list of the major joints of the body and their actions

Major Ligaments of the body

a. **Nuchal ligament** – binds spinous processes of the cervical vertebrae together; serves as the origin for the trapezium and splenius capitis muscles
b. **Acromioclavicular (AC) ligament -** binds the distal end of the clavicle with the acromion process; injured in a shoulder separation
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f. **Anterior talofibular ligament** – binds the distal fibula with the talus; crosses the anterolateral aspect of the ankle joint; usually damaged in a common ankle sprain (inversion sprain).

THE SKELETAL SYSTEM

FUNCTIONS OF THE BONE:

A. ***Supports*** and gives shape to the body
B. ***Protects*** internal organs
C. Helps make ***movements*** possible
D. ***Stores*** calcium
E. ***Hemopoiesis*** or blood cell formation

TYPES OF BONES:

A. *Long:* ex: humerus (upper arm)
B. *Short:* ex: carpals (wrist)
C. *Flat:* ex: frontal (skull)
D. *Irregular:* ex: vertebrae (spinal cord)

STRUCTURE OF LONG BONES:

A. Structural components

a. ***Diaphysis*** or shaft
b. ***Medullary cavity*** containing yellow marrow
c. ***Epiphyses*** or ends of the bone; spongy bone contains red bone marrow
d. ***Articular cartilage*** covers epiphyses as a cushion
e. ***Periosteum*** is strong membrane covering bone except at joint surfaces
f. ***Endosteum*** lines the medullary cavity

MICROSCOPIC STRUCTURE OF BONE AND CARTILAGE

A. Bone types

a. Spongy

i. Texture results from needlelike threads of bone called trabeculae surrounded by a network of open spaces
ii. Found in epiphyses of bones
iii. Spaces contain red bone marrow

b. Compact

i. Structural unit is osteon (Haversian system) composed of concentric lamella, lacunae containing osteocytes and canaliculi, all covered by periosteum

B. Cartilage

a. Cell type called chondrocytes
b. Matrix is gel-like and lacks blood vessels

BONE FORMATION AND GROWTH

A. Sequence of development early: cartilage models replaced by calcified bone matrix
B. **Osteoblasts** form new bone and **osteoclasts** resorb bone

DIVISIONS OF SKELETON

A. Skeleton composed of following divisions and their subdivisions:
    - **a. Axial skeleton**
        - i. Skull
        - ii. Spine
        - iii. Thorax
        - iv. Hyoid bone
    - **b. Appendicular skeleton**
        - i. Upper extremities, including shoulder girdle
        - ii. Lower extremities, including hip girdle
    - c. Location and description of bones

DIFFERENCES BETWEEN A MAN'S AND A WOMAN'S SKELETON

A. Size: males are generally larger
B. Shape of pelvis; male pelvis is deep and narrow, female pelvis is broad and shallow
C. Size of pelvic inlet: female pelvic inlet is generally wider, normally large enough for baby's head to pass though it
D. Pubic angle: angle between pubic bones and female generally wider

JOINT (ARTICULATIONS)

A. Kinds of joints
    - a. **Synarthrosis** (no movement) are made of fibrous connective tissue growing between articulating bones; for example, sutures of the skull
    - b. **Amphiarthrosis** (limited or slight movement) cartilage connects articulating bones for example the symphysis pubis
    - c. **Diarthroses** (freely movable joints) most joints belong to this class.
        - i. The structures of a diarthrosis are the join capsule and ligaments that hold adjoining bones together but permit movement at the joint
        - ii. **Articular cartilage** that covers joint ends of bones and absorbs jolts
        - iii. **Synovial membrane** that lines joint capsules and secretes lubricating fluids
        - iv. Joint cavity—spaces between joint ends of the articulating bones
B. Types of freely movable joints (6)—ball and socket, hinge, pivot, saddle, gliding, and **Condyloid**

SKELETAL DISORDERS

A. Bone tumors and cancer benign *or malignant **neoplasms** of bone, cartilage and fibrous tissue*

B. Metabolic bone disease
    - a. ***Osteoporosis***, excessive loss of bone matrix (mineral or collagen)
    - b. ***Osteomalacia***, softening of bone from loss of mineral (but not volume) in bone matrix; called rickets in children
    - c. ***Paget disease***, **Osteitis deformans**, abnormal bone remodeling in which spongy bone is replaced by disorganized, excessive bone matrix

C. Bone infection
    - a. ***Osteomyelitis***, general term for bacterial (usually staph)infection of bone

b. Bone *infections* may also be caused by viruses, fungi and other pathogens

D. Bone fractures

a. Open, compound fractures pierce the skin and closed (simple) fractures do not
b. Complete fractures involve total separation of the bone and fragments, and incomplete fractures involved partially separated fragments; comminuted fractures involve many fragments
c. Fracture lines can be classified by their angle relative to a bones axis: linear, transverse, and oblique

E. Joint disorders

a. *Non-inflammatory* joint disease does not usually involve inflammation of the synovial membrane
    i. Osteoarthritis—degenerative joint disease, degeneration of articular cartilage
    ii. Traumatic injuries: dislocation of articular surfaces is called subluxation; damage involving ligaments is called a sprain
b. Inflammatory joint disease (arthritis)—inflammation of synovial membrane with systemic signs or symptoms
    i. ***Rheumatoid arthritis***—autoimmune inflammation of synovial membrane and other structures; juveniles form is especially severe
    ii. ***Gouty arthritis***—synovial inflammation caused by gout, a condition in which sodium urate crystals form in joints and other tissues
    iii. ***Infectious arthritis***—arthritis resulting from infection by a pathogen, as in Lyme disease (arthritis) caused by the Lyme disease bacterium

VOCABULARY

Amphiarthrosis
Appendicular skeleton
Articular cartilage
Articulation
Axial skeleton
Canaliculi
Chrondrocytes
Compact bone
Diaphysis
diarthrosis
epiphyses
fontanels
Hemopoiesis
lacunae
lamella
medullary cavity
osteoblasts
osteoclasts
osteocytes
osteons
pectoral girdle
pelvic girdle
periosteum
red bone marrow
sinus
skull
spine
synarthrosis
synovial membrane
thorax
trabeculae
vertebroplasty
yellow bone marrow

DISEASES AND OTHER CLINICAL TERMS

Arthritis
Callus
Chondrosarcoma
Closed fracture
gout
incomplete fracture
Kyphosis
linear fracture
oblique fracture
open fracture
osteoarthritis
osteomalacia
Paget disease
rheumatic arthritis
rickets
scoliosis

Comminuted fracture	lordosis	Osteomyelitis	sprain
Complete fracture	mastoiditis	osteoporosis	transverse fracture

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The Skeleton

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   i. Examples: sutures and epiphyseal (growth) plates
b. **Cartilaginous joints** (amphiarthrosis) – slightly movable joints; articulating surfaces of the bones are separated by a piece of cartilage' also called amphiarthroses;
   i. examples: intervertebral disks and the pubic symphysis
c. **Synovial joints** (diarthrosis) – freely movable joints; possess a joint cavity encapsulated by ligamentous structures [joint capsule and/or

ligaments]; contain synovial fluid that is secreted by the synovial membrane; ends of joints are lined with hyaline cartilage; also called diarthroses.

d. Six types of Synovial Joints:
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Joint Structure: diarthrosis (synovial joints)

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DISEASES OF THE SKELETAL SYSTEM

BONE FRACTURES –

a. Massage considerations with fractures: work proximal and distal to the site of injury but not on the fracture until complete union occurs (usually 6 to 8 weeks from injury, depending on individual factors such as age) obtain approval of client's doctor before performing bodywork
b. Simple (closed) fracture – a complete break in a bone without protrusion from the skin
c. Compound (open) fracture – a complete break in a bone with protrusion of the bone from the skin
d. Comminuted fracture – a bone broken into several pieces (shattered)
e. Greenstick fracture – an incomplete break in a bone
f. Stress (fatigue) fracture – tiny, sometimes microscopic, fracture in the bone.
g. Impacted fracture – one end of a broken bone in pushed into the other broken end of the bone
h. Avulsion fracture – a piece of a bone is shipped or broken off
i. Depressed fracture – a broken portion of a bone is pushed inward (e.g. skull fracture)
j. Spiral fracture – "twisting" fracture in which the fracture line wraps around a bone
k. Nonunion – failure of the fractured ends of a bone to unite
l. Malunion – faulty or poor union of the two fractured ends of a bone.

SKELETAL DISORDERS

a. **Kyphosis** – (hyperkyphosis) exaggerated posterior curvature of the thoracic spine
    i. Causes; spinal disorders (e.g. bone disease, poor posture, weakened ligaments) resulting from trauma
    ii. Contraindications/indications – do not massage in severe cases, consult with client's physician
b. **Lordosis** (hyperlordosis) – exaggerated anterior curvature of the lumbar spine
    i. Causes: spinal disorders (e.g. bone disease, poor posture, weakened ligaments, resulting from trauma
    ii. Contraindications/indications – do not massage in severe cases; consult with client's physician
c. **Scoliosis** – lateral curvature of the spine; often creates a hanging arm length discrepancy and a "full chest" on the contralateral side; bracing is a common treatment; surgery is rare (only is condition is severe)
    i. Causes – leg length discrepancy, spina bifida, spinal nerve root damage
    ii. Contraindications/indications – do not massage in severe cases; consult with client's physician
d. **Cleft palate** – (a cleft lip or harelip (failure of the soft tissue over the lip to close together may accompany a cleft palate) – failure of the palatine

processes of the maxillae bones in the face to fuse during fetal development
    i. Causes – nutritional deficiencies, genetic error
    ii. Contraindications/indications – consult with client's doctor; avoid the area if painful

e. **Osteoporosis** – (osteo = bone; porosis – porosis) loss of bone tissue leading to weak, fragile bones; commonly leads to postural changes of the spine and the bone fractures in the pelvis, hips, wrists, and vertebrae.
    i. Cause: unknown, influenced by hormonal imbalances and insufficient levels of Vitamin D or calcium
    ii. Contraindications/indications: all bodywork should be light because although bones of the pelvis, lumbar and cervical spine are most affected, all bones may be brittle, consult with client's doctor.

f. **Osteogenesis imperfecta** – defective development of connective tissue, particularly bone tissue; bone tissue becomes thin and fragile and often bows under weight-bearing forces; often accompanied by multiple bone fractures.
    i. Cause: genetic trait causing abnormal synthesis of collagen, an elastic protein that make up about 90 percent of the bone tissue
    ii. Contraindications/indications: massage is most often contraindicated; consult with client's doctor

g. **Osteitis deformans** (*Paget's disease*) – common chronic condition characterized by disorganized bone tissue reabsorption and reformation leading to thinning and thickening of bone tissue and overall brittle bones, microfractures are common' may be accompanied by deformed teeth, skull enlargement, osteoarthritis, nerve compression, and faulty hearing.
    i. Cause: slow viral infection affecting osteoblasts and osteoclasts
    ii. Contraindication/indication: massage is contraindicated because bones are fragile

h. **Osteomalacia** (*rickets* in small children) – softening of bone and loss of bone mass, common in underdeveloped countries
    i. Cause: vitamin D deficiency
    ii. Contraindications/indications: massage is contraindicated because of the fragile condition of the bones.

i. **Osteomyelitis** – painful infection of the bone tissue and bone marrow; sometimes pus-filled abscesses form' leads to necrosis and destruction of bone tissue.
    i. Cause: staphylococcal or streptococcal infection resulting from bone fracture, surgery or penetrating wound
    ii. Contraindications/indications: massage is contraindicated; consult with client's physician.

Diseases of the Joints (articulations)

General Terminology:

a. **Dislocation** – displacement of a bone from its joint; usually involves damage to the surrounding tissue (e.g. ligaments, joint capsule, nerves).
   i. Cause: trauma
   ii. Contraindications/indications; refer to doctor; do not try to replace ("set") a dislocation; energy work is appropriate, but no stretching or massage should be done until pain and inflammation subside.

b. **Subluxation** – partial dislocation of a bone from its joint; sometimes referred to as a double-jointedness, usually follows a ligament injury.
   i. Causes: previous trauma; ligament injury, lax ligaments
   ii. Contraindications/indications: use caution; energy work can be effective, may be advisable to consult with client's doctor.

DISORDERS:

c. **Bursitis**: inflammation of the fluid-filled pad between tendon and bone (i.e. the bursa)
   i. Causes; infection, trauma, overuse
   ii. Contraindications/indications: avoid deep work on affected areas (in acute cases massage can increase the existing inflammation); use caution around all painful areas

d. **Tendonitis**: inflammation of a tendon
   i. Causes: infection, trauma, overuse
   ii. Contraindications/indications: avoid any areas that have acute inflammation

e. **Osteoarthritis:** most common degenerative joint disease; progressive, unsymmetrical deterioration and breakdown of articular cartilage, mainly in weight-bearing joints; loose bodies may develop in the joint space and react with the synovial membrane to cause pain; bone spurs may develop as a result of damage of the joint capsule; so known way of arresting osteoarthritis once it has had an effect; treatment includes weight loss, reduced activity and replacement of the affected joint.
   i. Cause: "wear and tear" on the joint, leading to death of chondrocytes and subsequent thinning and degeneration of articular cartilage
   ii. Contraindications/indications: avoid areas of inflammation; be cautions of possible bone spurs.

f. **Rheumatoid arthritis**: severe form of chronic synovitis; stiffness and pain result from thickening synovium and projection of synovium into the joint; inflammation of the smaller joints of the hands, wrists, ankles and feet is very common and symmetrical (affects both sides of the boy equally),, may also affect the heart, lungs, and skin; signs include ulnar deviation of the fingers and radial deviation of the wrist
   i. Cause autoimmune reaction, usually initiated by an infection
   ii. Contraindications/indications: avoid affected joints when in an acute and inflamed stage; paraffin bath is the medical treatment of choice.

g. **Gout**: a metabolic disorder involving the development of tophi (masses of uric acid crystals with macrophages and scar tissue cells) in and around joints and the ear lobes; 75% of attacks involve the great toe, but other joints often become involved; affected joints are inflamed, red, and very tender; acute episodes can subside within 3 to 10 days.
    i. Cause: 90% of cases are in the urine; predisposing factors include high alcohol intake, excessive red meat in diet, and obesity.
    ii. Contraindication/indications: avoid affected joints when in an acute and inflamed stage; refer to doctor
h. **Osgood-Schlatter disease**: partial separation (avulsion) of the tibial tuberosity from the tibial shaft resulting in inflammation of the bone and connective tissue of the anterior knee, usually occurs in male children 10 to 16 years of age (i.e. during puberty); calcification of the tibial tuberosity is incomplete, making it more easily fractured; symptoms include pain when kneeling, running, climbing stairs, or riding a bicycle and disappear at approximately 18 years of age; usually necessitates bracing or at least decreased activity levels for an extended period.
    i. Cause: "growth spurt" causing the bone to grow faster than the muscle and tendon.
    ii. Contraindication/indications: avoid the affected area
i. **Chodromalacia patellae**: softening and deterioration of the articular cartilage on the posterior patella; pain usually experienced when forcefully extending the knee.
    i. Causes: instability of the knee, substantial misalignment of the patella on the femur overuse; chronic Subluxation of the patella.
    ii. Contraindication/indications: obtain advice and approval of client's doctor before performing bodywork because of potential damage (particularly in acute cases); massage to and stretching the quadriceps would be beneficial and could relieve the pain.
j. **Temporomandibular joint dysfunction** (TMJ dysfunction or TMD) – any kind of abnormal functioning of the temporomandibular joint.
    i. Causes: trauma (often from motor vehicle accidents); poor posture, overuse from bruxism (teeth grinding)
    ii. Contraindications/indications: condition can change the position of the jaw, causing natural teeth, dentures or bridges to fit together improperly, massage can relax muscles and relieve symptoms, work with dentist or physician, if necessary.
k. **Degenerative disk disease**: deterioration of the intervertebral disks in the spinal column; 80% of damage occurs in the posterior half of the disk. Repetitive movements cause fissuring in the annulus fibrosis, which allows the nucleus pulposus to migrate into the fissure, reducing the potential for the annulus to heal. Increased pressure in the outer annulus may cause pain or paresthesia in the back or trunk (nerves are present in the outer third of annulus), or the pain may refer to the lower extremities; nuclear migration also leads to protrusion of the disk into the intervertebral foramen, which puts pressure on the nerve root, causing weakness and pain in the lower extremities.
    i. Causes: poor posture; repetitive movements of the spine such as flexion combined with rotation when carrying or lifting heavy

objects; low tension for long periods can cause the same amount of damage as high tension for short periods.

ii. Contraindications/indications: do not massage painful areas; consult with client's physician.

The Skeletal System

Lecture SYNOPSIS

Covers the generalized functions and support mechanisms of the skeletal system. The types of bone and the microscopic structures that make up bone during growth and formation are identified.
Divisions of the skeletal system are explained—the axial skeleton and the appendicular skeleton. A major overall function of the skeletal system is support and protection of the body's internal organs. Bones make movement possible, store substances such as lipids and calcium, and are the site for hemopoiesis (red cell formation) in red bone marrow. Also discussed in this chapter are the different types of joints and their importance in the various types of movement they facilitate.

LEARNING OBJECTIVES WITH RATIONALE
the student will be able to:

1. List and discuss the generalized functions of the skeletal system.

The following functions are performed by the skeletal system:

a**. Support**—The skeletal system is a bony framework that supports tissues and organs.
b. **Protection**—It encases delicate organs.
c. **Movement**—Muscles are anchored to bones and, as they contract, they pull on and move bones.
d. **Storage**—Bones maintain homeostasis of blood calcium. When the amount of calcium in blood increases to above normal, calcium moves out of blood and into bones for storage. When blood calcium decreases to below normal, it comes out of storage and enters the blood.
e. **Hemopoiesis**—Red bone marrow makes blood cells.

2. Identify the major anatomical structures found in a typical long bone and discuss bone formation.

A typical long bone is made up of the following structures:

a. **Diaphysis** or shaft—a hollow tube made of compact bone
b. **Medullary cavity**—the hollow area inside the diaphysis that contains soft yellow bone marrow
c. **Epiphyses**—ends of bone made of spongy bone and filled with red bone marrow
d. **Articular cartilage**—thin layer of cartilage covering each epiphysis; acts as a cushion between joint surfaces
e. **Periosteum**—a strong, fibrous membrane that covers a long bone everywhere except at its joint surfaces

--*When the skeleton first forms in a baby, it is made up of cartilage*. Cartilage is gradually replaced
with calcified bone matrix as a result of the activity of bone-forming cells called osteoblasts. Osteoblasts lay down calcium salts in the gel-like matrix of bone.

--A long bone grows from a center in its diaphysis and from centers in the layers of cartilage that

separate each of the epiphyses from the diaphysis. The diaphysis grows in both directions toward both epiphyses, and both epiphyses grow toward the diaphysis. *As long as any epiphyseal cartilage remains, this two-way growth continues.* It ceases when all the epiphyseal cartilage has been transformed into bone.

3. Discuss the microscopic structure of bone and cartilage, including the identification of specific cell types and structural features.

--Two types of bone can be identified in the skeleton: spongy and dense (or compact).

--Spongy bone (aka cancellous bone) is very porous and contains a network of spaces called trabeculae. These spaces are filled with bone marrow.

--Compact (aka dense) bone is organized into structural units called Haversian systems. These units are circular and tube like in shape, arranged in ring like calcified layers called lamellae. Lamellae surround a space called the Haversian canal, and blood vessels, which nourish bone, pass through this canal. Bone-forming cells, called osteocytes, are found in small spaces called lacunae that exist between the lamellae. Radiating from the lacunae are canals called canaliculi. Nutrients reach osteocytes through these canals.

--Cartilage is made up of fibers that are embedded in a firm gel instead of in a calcified cement substance as they are in bone. Cartilage is, therefore, more flexible. Cartilage cells are called chondrocytes and, like osteocytes of bone, are located in lacunae. *Cartilage contains no blood vessels, so nutrients must diffuse through the matrix to reach the cells*.

4. Explain how bones are formed, how they grow, and how they are remodeled.

--The skeleton, which forms while the baby is in utero, consists of cartilage and fibrous material such as bone. The calcification process is what makes bones hard. A long bone grows from a center in its diaphysis and from other centers in the layers of cartilage. The diaphysis grows in both directions toward both epiphyses, and both epiphyses grow toward the diaphysis.

Remodeling occurs when old bone is replaced by new bone.

5. Identify the two major subdivisions of the skeleton and list the bones found in each area.

--*The human skeleton has two divisions: the axial skeleton and the appendicular skeleton.*

--The axial division is made up of the following bones: frontal, parietal, temporal, occipital, sphenoid, ethmoid, nasal, maxillary, zygomatic, mandible, lacrimal, palatine, inferior turbinate, vomer, malleus, incus, stapes, hyoid, vertebrae, sacrum, coccyx, ribs, and sternum.

--The appendicular division is made up of clavicle, scapula, humerus, radius, ulna, carpals, metacarpals, phalanges, hip bones, femur, patella, tibia, fibula, tarsals, and metatarsals.

6. List and compare the major types of joints found in the body and give an example of each type.

--Based on the degree of movement they allow, three types of joints can be identified in the body.

a. **Synarthroses** are joints that *allow no movement*. Sutures, or joints between the cranial bones, are synarthroses.

b. **Amphiarthroses** are *slightly moveable joints*. The symphysis pubis and the joints between bodies of vertebrae are amphiarthroses.

c. **Diarthroses** are *freely moveable joints*. There are several types of diarthroses. In ball-and-socket types (hip and shoulder joints), a ball-shaped head of one bone fits into a concave socket of another bone. These joints allow flexion, extension, abduction, adduction, and circumduction. In hinge type (elbow and knee joints), only flexion and extension are allowed. Pivot joints (joint between axis and atlas) are those in which a small projection of one bone pivots in an arch of another bone. Saddle joints (between metacarpal bone of thumb and carpal bone of wrist) have articulating surfaces that are saddle-shaped, and these joints exhibit all kinds of movement.

LECTURE OUTLINE

I. FUNCTIONS OF SKELETAL SYSTEM

A. Supports and gives shape to the body
B. Protects internal organs
C. Helps make movements possible
D. Stores calcium
E. Hemopoiesis or blood cell formation

II. TYPES OF BONES

A. Long—example: humerus (upper arm)
B. Short—example: carpals (wrist)
C. Flat—example: frontal (skull)
D. Irregular—example: vertebrae (spinal cord)

III. STRUCTURE OF LONG BONES

A. Structural components
    1. Diaphysis or shaft
    2. Medullary cavity containing yellow marrow
    3. Epiphyses or ends of the bone; spongy bone contains red bone marrow
    4. Articular cartilage—covers epiphyses as a cushion
    5. Periosteum—strong membrane covering bone except at joint surfaces
    6. Endosteum—lines medullary cavity

IV. MICROSCOPIC STRUCTURE OF BONE AND CARTILAGE

A. Bone types
    1. Spongy (cancellous)
        a. Texture results from needlelike threads of bone called trabeculae surrounded by a network of open spaces
        b. Found in epiphyses of bones
        c. Spaces contain red bone marrow
    2. Compact (dense)
        a. Structural unit is Haversian system—composed of concentric lamella, lacunae containing osteocytes, and canaliculi, all covered by periosteum
B. Cartilage
    1. Cell type called chondrocyte
    2. Matrix is gel-like and lacks blood vessels

V. BONE FORMATION AND GROWTH

A. Sequence of development early—cartilage models replaced by calcified bone matrix
B. Osteoblasts form new bone, and osteoclasts resorb bone

VI. DIVISIONS OF SKELETON

Skeleton composed of the following divisions and their subdivisions:
A. Axial skeleton
    1. Skull
    2. Spine
    3. Thorax
    4. Hyoid bone
B. Appendicular skeleton
    1. Upper extremities, including shoulder girdle
    2. Lower extremities, including hip girdle
C. Location and description of bones

VII. DIFFERENCES BETWEEN A MAN'S AND A WOMAN'S SKELETON

A. Size—male skeleton generally larger
B. Shape of pelvis—male pelvis deep and narrow; female pelvis broad and shallow
C. Size of pelvic inlet—female pelvic inlet generally wider; normally large enough for baby's head to pass through it
D. Pubic angle—angle between pubic bones of female generally wider

VIII. JOINTS (ARTICULATIONS)

A. Kinds of joints (Figures 6-19 to 6-21)

1. Synarthroses (no movement)—fibrous connective tissue grows between articulating bones; for example, sutures of skull

2. Amphiarthroses (slight movement)—cartilage connects articulating bones; for example, symphysis pubis
3. Diarthroses (free movement)—most joints belong to this class
    a. Structures of freely movable joints—joint capsule and ligaments hold adjoining bones together but permit movement at joint
    b. Articular cartilage—covers joint ends of bones and absorbs jolts
    c. Synovial membrane—lines joint capsule and secretes lubricating fluid
    d. Joint cavity—space between joint ends of bones
B. Types of freely movable joints—ball-and-socket, hinge, pivot, saddle, gliding, and condyloid

Review Questions

1. List and briefly explain the five functions of the skeletal system.

Answer: (1) Support—bones form the body's supporting framework, giving it shape.
(2) Protection—protects the internal organs and delicate structures that lie within.
(3) Movement—as muscles contract they shorten and pull on bones, which then move.

(4) Storage—bones store calcium to maintain bone and blood homeostasis.
(5) Hemopoiesis—the process of blood cell formation.

2. Describe the structure of the osteon.

Answer: The matrix is organized into numerous structural units called osteons or Haversian systems. The compact bone forming the hard shell of the bone is constructed of cylindrical units called osteons. Each circular and tube like osteon is composed of calcified matrix arranged in multiple layers resembling rings called concentric lamellae. The circular rings or lamellae surround the central canal, which contains a blood vessel.

3. Describe the structure of cartilage.

Answer: Cartilage is made up of fibers that are embedded in a firm gel that makes them more flexible. Cartilage cells are called chondrocytes and are located in lacunae. Because cartilage contains no blood vessels, nutrients must diffuse through the matrix to reach the cells.

4. Explain briefly the process on endochondral ossification. Include the function of the osteoblasts and osteoclasts.

Answer: Most bones are formed from cartilage models. This process is called endochondral ossification, meaning formed in cartilage. Invasion of the diaphysis (shaft) by blood vessels and the combined action of osteoblasts (bone-forming cells) and osteoclasts (bone-resorbing cells) result in cavity formation, calcification, and the appearance of bone tissue, as well as ossification in the epiphyses (ends) of the bones.

5. Explain the importance of the epiphyseal plate.

Answer: The epiphyseal plate (growth plate) is made of cartilage that lies between the epiphysis and the diaphysis and allows growth to occur. Growth ceases when all epiphyseal cartilage is transformed into bone. All that remains is an epiphyseal line that marks the area where two centers of ossification have fused together.

6. In general, what bones are included in the axial skeleton and the appendicular skeleton.

Answer:
~Axial skeleton: Skull, spine, thorax, hyoid bone

~Appendicular skeleton: Upper extremities, including shoulder girdle; lower extremities, including hip girdle

7. The vertebral column is divided into five sections based on location. Name the sections and give the number of vertebrae in each section.

Answer:
~7 cervical vertebrae—located in the upper neck region. The first cervical vertebra is called atlas, the second axis

~12 thoracic vertebrae—located in the center of the back, following the 7 cervical vertebrae

~5 lumbar vertebrae—located in the small of the back
~1 sacrum—In a child there are five separate vertebrae that form the sacrum; in an adult the vertebrae are fused into one
~1 coccyx—In a child there are three to five separate vertebrae; in an adult the vertebrae are fused into one

8. Distinguish between true, false, and floating ribs. How many of each are there?

Answer:
~There are 14 true ribs (seven pairs). The upper 7 pairs are attached to the sternum by costal cartilages.

~There are 10 false ribs (five pairs). The ribs numbered 8, 9, and 10 are not attached to the sternum, but to the cartilage of the 7th ribs, and therefore are called false ribs.

~The last two pairs (ribs 11 and 12) are not attached to any costal cartilage and seem to float free in front and thus are called floating ribs.

9. Describe and give an example of a synarthrotic joint.

Answer: A synarthrotic joint has fibrous connective tissue growing between articulating bones, holding them close together. An example of this type of joint is the cranial bones in which there is no movement.

10. Describe and give an example of an amphiarthrotic joint.

Answer: An amphiarthrotic joint has cartilage connecting articulating bones. The following are examples of amphiarthrotic joints (capable of slight movement): the symphysis pubis, which has a joint between the two pubic bones; and the vertebrae, which have joints between the bodies of the vertebrae.

11. Describe and give an example of two types of diarthrotic joints.

Answer: Diarthrotic joints are freely movable and all have a joint capsule, a joint cavity, and a layer of cartilage over the ends of two joining bones. In a ball-and-socket joint, a ball-shaped head of one bone fits into a concave socket of another bone, as in the shoulder and hip joints. With the hinge joint, movement is possible in only two directions, as in the elbow and knee.

12. Briefly describe a joint capsule.

Answer: A joint capsule is made of the body's strongest and toughest material, fibrous connective tissue and is lined with a smooth, slippery synovial membrane. The capsule fits over the ends of two bones, holding the bones securely together, but at the same time permitting movement at the joint.

Critical Thinking Questions

13. When a patient receives a bone marrow transplant, what vital process is being restored?

Answer: Red bone marrow is soft connective tissue inside the hard walls of some bones. The term **hemopoiesis** is used to describe the process of blood cell formation, which is carried on in red bone marrow. A transplant of bone marrow is a procedure that can possibly restore or enhance the body's ability to form blood cells.

14. Explain how the canaliculi allow bone to heal more efficiently than cartilage.

Answer: The tiny passageways or canals, called canaliculi, connect the lacunae with the central canal in each Haversian system. Nutrients pass from the blood vessel in the Haversian canal through the canaliculi to the osteocytes where the infected or damaged area can be nourished and healing can begin. Because there are no blood vessels in cartilage, nutrients must diffuse through the matrix to reach the cells. Because of the lack of blood vessels, cartilage rebuilds itself very slowly after an injury.

15. What effect does the task of childbearing have on the differences between the male and female skeleton?

Answer: The structural differences between the male and female skeleton do have functional differences in regard to childbearing. In the female, the hip bones are made so that the body of the baby can be cradled in the mother's body before birth, whereas the male hip bones are usually larger and more narrow. The female pelvis is broader, shallower, and more like a basin, with the inlet and outlet of the pelvis much wider, thereby allowing more space for the passage of the baby during childbirth. The male pelvis is shaped like a funnel with less space in the inlet and outlet areas.

CLASSROOM APPLICATION

The following questions can be used as individual assignments or for small-group discussion. Note: to copy the questions, cover the answers with a blank sheet of paper and print, thus leaving space for answers or note-taking.

1. You have noticed recently that your grandmother seems to be walking with a slight stoop to her posture. She mentioned that at her last doctor visit, he told her she had the beginning stages of osteoporosis. What do you know about osteoporosis?

A. Define osteoporosis.
B. What are some of the physiological changes that occur?
C. Who is most likely to be afflicted?
D. What are some of the preventive measures and what type of treatment is available?

Answer:
A. Osteoporosis is a bone disease in which there is an excessive loss of calcified matrix and

collagenous fibers from bone.
B. Physical signs include bone degeneration, spontaneous fractures, and curvature of the spine.
C. Elderly white females are affected most frequently.
D. Prevention and treatment may include sex hormone therapy, and dietary supplements of calcium and vitamin D.

2. After falling off a pile of rocks while playing near his home, 13-year-old Nick has a great deal of pain in his elbow. Nick's doctor takes a radiograph (x-ray photograph) of the arm and states that Nick has "twisted the end of one of his bones off." What does the doctor mean by this

Answer: The doctor was referring to an epiphyseal fracture—a break at the epiphyseal plate) in bones that are not quite finished growing. Obviously the doctor meant that Nick's bone had broken in a way that separated an epiphysis (end of one of his bones) from the diaphysis (the shaft) at the epiphyseal plate.

3. Nick's dad fell off of a ladder the previous week while working at a construction site. The accident was nearly the same: same distance fallen, same parts of the body hit with the same or more force as in Nick's accident. However, Nick's dad did not suffer a fracture like Nick's. Why is the doctor not surprised? (Hint: Think about Nick's age compared to his dad's age.)

Answer: Nick's father may have sustained the same forces or stresses to his bones as Nick, but being an adult, his skeleton has stopped the developmental phases. In short, the father's bones have lost their epiphyseal plates by fusing the epiphyses to the diaphysis to form continuous, solid bone. Thus, although Nick's dad may have suffered some injuries, it is not likely that he would suffer an epiphyseal fracture because there is no longer a weak epiphyseal plate in any of his arm bones.

PRACTICAL/CREATIVE LEARNING ACTIVITIES

1. Identify for students the cranial and facial bones on a skeletal model.

2. Demonstrate for students the different types of diarthrotic joints on your own body or on a skeleton.

3. Use a skeletal model and have students identify the axial skeleton and the appendicular skeleton.

4. Have students use anatomy coloring books or diagrams of bone to identify components in the axial and the appendicular skeletal systems.

STUDENT ASSIGNMENT
THE SKELETAL SYSTEM

Complete the following statements using the terms below. Write the words below on the board and then read the following statements, having the students fill in the correct answers.

A. Osteoporosis	G. Cartilage
B. Spongy bone	H. Frontal

C. Appendicular	I. Clavicle
D. Hemopoiesis	J. Carpals
E. Humerus	K. Axial skeleton
F. Scapula	L. Diarthroses

1. When the skeleton first forms in a baby, it is made up of _____.

2. This type of bone is very porous and contains a network of spaces called trabeculae. It is called _____ bone.

3. An example of a long bone is _____.

4. An example of a short bone is _____.

5. This bone disease is characterized by excessive loss of calcified matrix and collagenous fibers from the bone. It is known as _____.

6. Blood cell formation is termed _____.

7. The human skeleton has two divisions: the _____ and the _____.

8. The forehead bone is called the _____ bone.

9. Two bones compose the shoulder girdle. They are the _____ and the _____.

10. A joint that is freely movable is called _____.

True or False

Indicate whether the following statements are true (T) or false (F).

11. The phalanges of the foot are similar to those of the hand. T or F

12. The first seven pairs of ribs are connected directly to the spine. T or F

13. The cervical and lumbar curves are convex. T or F

14. Sutures are found between the bones of the skull and are immovable. T or F

15. Bursitis is an inflammation of the bursae. T or F

Define the following vocabulary words:

Amphiarthroses_____

Appendicular skeleton_____

Arthritis_____

Axial skeleton_____

Bursitis_____

Compact bone_____

Diaphysis_____

Diarthroses_____

Epiphysis_____

Fontanels_____

Haversian System_____

Hemopoiesis_____

Medullary cavity_____

Pelvic girdle_____

Red bone marrow_____

Spongy bone_____

Synarthrosis_____

Synovial joint_____

THINK ABOUT IT:
Mrs. Theresa Kittrell brought her son John, age 12, to the emergency room with an injured right leg. After performing a thorough examination and reading the x-rays that were taken, the doctor tells Mrs. Kittrell that her son has an epiphyseal fracture.

What fact is true about the epiphyseal area mentioned by the doctor?

A. It continues to grow throughout the person's life.
B. It lies in the center of long bones.
C. It contains yellow bone marrow.
D. It can reveal evidence of continued bone growth.

The doctor suggests that John refrain from playing football, even after the injury to his leg heals, because of his age. What is the reasoning behind this advice? Circle all that apply.

A. Epiphyseal fractures are more common in children John's age.
B. Long bones during the growth period are more susceptible to injury.
C. Stress at the point of articulation in growing long bones causes greater risk of damage.
D. With an epiphyseal fracture, the epiphyseal plate can be separated from the diaphysis or epiphysis.

Which type of movement produces skeletal muscle contraction?

A. dorsiflexion
B. adduction
C. extension
D. all of the above

Which of the following statements concerning the ribs is true?

A. The first seven pairs attach to the sternum by cartilage.
B. The last four pairs are called floating ribs because they are free in the front.
C. The eighth, ninth, and tenth pairs do not move because they are not attached to the sternum.
D. All of the above statements concerning the ribs are true.

Which is the largest bone in the lower extremities?

A. humerus
B. ulna
C. femur
D. radius

Of what is yellow bone marrow primarily made?

A. fatty tissue
B. blood cells
C. epithelial tissue
D. fibrous tissue

Which of the following statements regarding the female pelvis is not true?

A. Its shape can be described as broader, shallower, and basin like when compared to that of the male.
B. Its pelvic inlet, or brim, is usually wider than that of the male.
C. Its individual bones are usually larger and heavier than those of males.
D. All of the above statements are true.

Which of the following statements are true about the normal curves of the spine?

A. They are present at birth.
B. They extend from the skull to the bottom of the ribcage.
C. They give the spine strength to support the weight of the rest of the body.
D. All of the above are true.

Which of the following statements regarding diarthroses is not true?

A. They contain a synovial membrane that secretes a lubricating fluid called synovial fluid.
B. A diarthrotic joint may permit flexion, extension, abduction, adduction, or rotation.
C. These joints make up the largest part of body joints.

D. All of the above statements are true.

Which of the following bones are components of the axial skeletal system?

A. ilium, ethmoid, clavicle
B. ulna, palatine, occipital
C. sacrum, vomer, sphenoid
D. scapula, patella, fibula

Which of the following bones is not classified as a cranial bone?

A. sphenoid
B. parietal
C. palatine
D. temporal

Which of the following statements characterizes the skeleton of a growing child?

A. Epiphyses are separated from diaphysis by a layer of cartilage.
B. Osteoblasts deposit calcium in the gel-like matrix of cartilage.
C. The periosteum is present.
D. All of the above statements characterize the skeleton of a growing child.

What are the joints between the cranial bones called?

A. synarthroses
B. diarthroses
C. amphiarthroses
D. all of the above