Anatomy and Physiology: The Skeletal System

AI-Generated Study Guide

(Based on lectures delivered by Dr. Ty C.M. Hoffman)

I. Functions of the Skeletal System

- **Support:** Provides the rigid framework for the body.
- **Protection:** Encloses and safeguards vital organs (e.g., rib cage protects lungs and heart, cranium protects the brain).
- **Movement:** Serves as attachment points for muscles; muscles pull on stiff bones to produce body movement.
- **Breathing:** Ribs, pulled by muscles, increase lung volume during inhalation.
- **Mineral Storage:** Acts as a large reservoir for calcium and phosphate in the form of hydroxyapatite. These minerals are crucial for various bodily functions, including heart contraction, muscle movement, and plasma membrane formation. The skeleton helps maintain homeostasis by releasing or storing these ions as needed.
- **Hemopoiesis (Hematopoiesis):** The production of all blood cells (red and white) occurs in the red marrow within the bones.

II. Bone Tissue

- **Two Kinds of Bone Tissue:Compact Bone:**Much denser and stronger due to less space.
- Forms the superficial layer of all bones.
- Composed of cylindrical units called **osteons**.
- Each osteon has a **central canal** for blood vessels and nerves.
- Osteons are made of concentric layers of hard material called **lamellae**.
- **Spongy Bone:**Located deep to compact bone.
- Looks like a sponge due to many pores/holes, but is still hard.
- Lighter than compact bone, reducing overall skeletal weight while maintaining strength.
- The holes are spaces between tiny beam-like structures called **trabeculae**.
- Contains **marrow** (red and yellow).
- **Marrow:Red Marrow:** Site of hemopoiesis (blood cell production).

- **Yellow Marrow:** Primarily composed of fat; fat storage.
- **Extracellular Matrix:** The hard, non-cellular component of bone tissue, primarily made of **hydroxyapatite** (calcium phosphate).

III. Bone Cells

- **Osteoblasts:** Cells responsible for building and secreting the extracellular matrix of bone.
- **Osteocytes:** Mature bone cells, derived from osteoblasts, that maintain the extracellular matrix. They are found within small spaces called **lacunae**.
- **Osteoclasts:** Cells that degrade and break down the extracellular matrix, releasing minerals (like calcium and phosphate) into the blood.

IV. Bone Development and Remodeling

- **Ossification:** The process of cartilage or connective tissue turning into bone.
- Most bones begin as **hyaline cartilage**.
- Skull bones begin as connective tissue membranes.
- **Bone Growth (Long Bones):**Long bones have a central shaft (**diaphysis**) and two ends (**epiphyses**).
- Growth in length occurs at **epiphyseal plates** (growth plates), which are made of cartilage between the diaphysis and epiphyses.
- New material is added towards the diaphysis, causing the bone to lengthen.
- Around age 20, the epiphyseal plates ossify and become **epiphyseal lines**, indicating the cessation of longitudinal growth.
- **Medullary Cavity:** The open, internal space within the diaphysis of long bones, which contains marrow.
- **Bone Remodeling:** The continuous process throughout life where bone tissue is partially destroyed by osteoclasts and rebuilt by osteoblasts. This allows the skeleton to adapt to stress and maintain mineral homeostasis.

V. Bone Healing (Fracture Repair)

1. **Hematoma Formation:** Blood vessels in the bone are severed, forming a large blood clot (hematoma) at the fracture site.
2. **Fibrocartilage Callus Formation:** The hematoma is gradually replaced by **fibrocartilage**, which is stronger than a blood clot but not yet bone.
3. **Bony Callus Formation (Ossification):** The fibrocartilage ossifies, turning into a **bony callus** (hard bony material).

4. **Bone Remodeling:** The bony callus is remodeled over time, removing excess material and reshaping the bone to its original form, often resulting in a stronger fracture site than before.

VI. Divisions of the Skeleton

- **Axial Skeleton:** Bones located along the body's central axis.
- **Skull:Cranium (Brain Case):** 8 bones, in direct contact with the brain.
- **Facial Bones:** 14 bones, attached to the front of the cranium.
- **Vertebral Column (Spine):Cervical Vertebrae (C1-C7):** 7 bones, in the neck region. C1 (Atlas) supports the skull; C2 (Axis) allows head rotation. Unique with three holes.
- **Thoracic Vertebrae (T1-T12):** 12 bones, articulate with ribs. Look like "giraffe heads" from the side.
- **Lumbar Vertebrae (L1-L5):** 5 bones, in the lower back. Look like "moose heads" from the side, with large bodies for weight bearing.
- **Sacrum:** 5 fused vertebrae. Part of the pelvic girdle.
- **Coccyx (Tailbone):** 2-4 fused vertebrae.
- **Ribs:** 12 pairs (24 total).
- **True Ribs (1-7):** Connect directly to the sternum via their own costal cartilage.
- **False Ribs (8-12):** Do not connect directly to the sternum.
- Ribs 8-10: Connect to other rib cartilage.
- Ribs 11-12 (**Floating Ribs**): Do not connect anteriorly at all.
- **Sternum:** Breastbone, connects to ribs.
- **Appendicular Skeleton:** Bones of the limbs and their girdles, appended to the axial skeleton.
- **Pectoral Girdle:** Connects the upper limbs to the axial skeleton.
- **Clavicle (Collarbone):** 2 bones.
- **Scapula (Shoulder Blade):** 2 bones.
- **Upper Limbs:Humerus:** Bone of the arm (brachium).
- **Radius:** Forearm (antibrachium) bone, lateral when in anatomical position, rotates for pronation/supination.
- **Ulna:** Forearm (antibrachium) bone, medial, forms hinge joint with humerus.
- **Manus (Hand):Carpals:** 8 wrist bones.
- **Metacarpals:** 5 palm bones.
- **Phalanges:** 14 finger bones (2 in thumb, 3 in others).
- **Pelvic Girdle:** Connects the lower limbs to the axial skeleton.
- **Os Coxae (Pelvic Bones):** 2 bones, each formed from the fusion of three bones:
- **Ilium:** Superior, largest part.
- **Ischium:** Posterior, rounded part you sit on.
- **Pubis:** Anterior part, joins with the other pubis anteriorly.
- (Note: Sacrum is part of the axial skeleton but completes the pelvic girdle ring).
- **Lower Limbs:Femur:** Thigh bone, largest bone in the body.
- **Tibia:** Larger leg bone, medial, bears weight.

- **Fibula:** Smaller leg bone, lateral, for support, does not bear weight.
- **Patella:** Kneecap.
- **Pedis (Foot):Tarsals:** 7 ankle bones.
- **Metatarsals:** 5 arch bones.
- **Phalanges:** 14 toe bones (2 in great toe, 3 in others).

VII. Bone-Related Terminology

- **Articulation:** The formation of a joint between two bones.
- **Fontanelles:** Soft spots in a baby's skull, areas of dense connective tissue membranes that have not yet ossified into bone.
- **Sutures:** Immovable joints between the bones of the skull.
- **Intervertebral Discs:** Tough pads of fibrocartilage between vertebral bodies, allowing slight movement and cushioning.
- **Herniated Disc:** A bulging of an intervertebral disc that can press on spinal nerves, causing pain. (Often incorrectly called "slipped disc").
- **Scoliosis:** Abnormal lateral curvature of the vertebral column.
- **Kyphosis:** Exaggerated posterior (hunchback) curvature of the thoracic spine.
- **Lordosis:** Exaggerated anterior (swayback) curvature of the lumbar spine.
- **Sexing a Skeleton:** Identifying the biological sex, often by examining the pelvic girdle (U-shaped subpubic angle in females, V-shaped in males) or occipital protuberance.
- **U-shape vs. V-shape:** Refers to the subpubic angle of the pelvic girdle, used for sexing skeletons (U for female, V for male).

Quiz: The Skeletal System

Instructions: Answer each question in 2-3 sentences.

1. Beyond providing support and protection, explain two other vital functions of the skeletal system mentioned in the lecture.
2. Describe the key differences in structure and location between compact bone and spongy bone.
3. What are osteocytes, and what is their primary role within bone tissue?
4. Explain the process of hemopoiesis and where it specifically occurs within the skeletal system.
5. What is the significance of the epiphyseal plate in long bones, and what does its transformation into an epiphyseal line indicate?
6. Briefly describe the first two stages of bone fracture healing.
7. Identify the three main categories of vertebrae in the vertebral column, listed from superior to inferior, and state how many bones are in each category.
8. Distinguish between "true ribs" and "false ribs" based on their connection to the sternum.

9. Name the three bones that fuse to form each adult os coxa, and identify which one is the largest and most superior.
10. Describe the anatomical location and function of the hyoid bone, noting its unique characteristic among all bones.

Answer Key for Quiz

1. The skeletal system is crucial for body movement, as muscles pull on the rigid bones to facilitate locomotion. It also serves as a major reservoir for essential minerals like calcium and phosphate, releasing them into the bloodstream to maintain homeostasis for various bodily functions.
2. Compact bone is dense and forms the superficial layer of all bones, providing strength and protection. Spongy bone, found deep to compact bone, has a porous, "spongy" appearance due to trabeculae and contains marrow, making it lighter while retaining strength.
3. Osteocytes are mature bone cells derived from osteoblasts. Their primary role is to maintain the extracellular matrix of bone tissue, ensuring its structural integrity and participating in mineral homeostasis.
4. Hemopoiesis is the process of blood cell production, including both red and white blood cells. This vital function occurs specifically within the red marrow, which is found in the interior spaces of bones, particularly in spongy bone.
5. The epiphyseal plate is a cartilage growth plate in long bones, responsible for increasing bone length during growth. Its ossification into an epiphyseal line around age 20 signifies that longitudinal bone growth has ceased.
6. The first stage of bone fracture healing is hematoma formation, where severed blood vessels at the fracture site form a large blood clot. This hematoma is then gradually replaced by fibrocartilage in the second stage, forming a fibrocartilage callus that provides more stability.
7. The three main categories of vertebrae, from superior to inferior, are: Cervical (7 bones), Thoracic (12 bones), and Lumbar (5 bones).
8. True ribs (pairs 1-7) connect directly to the sternum via their own band of hyaline cartilage. False ribs (pairs 8-12) do not connect directly to the sternum; ribs 8-10 connect to other rib cartilage, and ribs 11-12 (floating ribs) do not connect anteriorly at all.
9. Each os coxa is formed by the fusion of the ilium, ischium, and pubis. The ilium is the largest and most superior part of the os coxa.
10. The hyoid bone is a U-shaped bone located in the neck, inferior to the mandible. Its unique characteristic is that it is the only bone in the body that does not articulate (form a joint) with any other bone; it serves as an attachment point for muscles involved in throat function.

Essay Format Questions

1. Discuss the dynamic nature of bone tissue, explaining how it is constantly changing through processes like remodeling and mineral storage, rather than being a static structure once formed.
2. Compare and contrast the structure and function of the axial and appendicular skeletons, providing specific examples of bones from each division and their roles.
3. Describe the sequence of events involved in the healing of a bone fracture, detailing the purpose and characteristics of each stage.
4. Explain how bone growth in long bones occurs, referencing the relevant anatomical structures, and discuss why this process eventually stops.
5. Detail the three main types of bone cells (osteoblasts, osteocytes, osteoclasts) and explain their distinct functions in maintaining and remodeling bone tissue, including their relationship to the extracellular matrix.

Glossary of Key Terms

- **Anatomical Position:** Standard reference position where the body is erect, feet together, arms at sides, palms forward.
- **Antibrachium:** Anatomical term for the forearm (between the elbow and wrist).
- **Appendicular Skeleton:** The part of the skeleton composed of the bones of the limbs and their girdles (pectoral and pelvic girdles).
- **Articulation:** The formation of a joint between two bones.
- **Atlas (C1):** The first cervical vertebra; supports the skull and allows for nodding movements.
- **Axial Skeleton:** The part of the skeleton forming the central axis of the body, including the skull, vertebral column, and rib cage.
- **Axis (C2):** The second cervical vertebra; allows for rotation of the head ("no" movement).
- **Bony Callus:** The hard, bony material that replaces the fibrocartilage callus during bone fracture healing.
- **Brachium:** Anatomical term for the arm (between the shoulder and elbow).
- **Calcification:** The process of calcium salt deposition in tissues, often leading to hardening.
- **Calcium Phosphate:** The chief chemical component of hydroxyapatite, providing hardness to bones.
- **Carpals:** The 8 bones of the wrist, part of the manus.
- **Central Canal:** The central passageway within an osteon, containing blood vessels and nerves.
- **Cervical Vertebrae:** The 7 vertebrae of the neck, numbered C1-C7; characterized by three holes.
- **Clavicle:** The collarbone, part of the pectoral girdle.
- **Coccyx:** The tailbone, formed by the fusion of 2-4 vertebrae.
- **Compact Bone:** Dense, superficial bone tissue with little space, providing strength.
- **Cranium:** The 8 bones of the brain case, part of the skull.

- **Diaphysis:** The shaft or central part of a long bone.
- **Digits:** Fingers or toes.
- **Epiphyseal Line:** A bony line in mature long bones where the epiphyseal plate once was, indicating no further longitudinal growth.
- **Epiphyseal Plate (Growth Plate):** A layer of hyaline cartilage in growing long bones, responsible for longitudinal growth.
- **Epiphysis:** The end part of a long bone, distinct from the diaphysis.
- **Extracellular Matrix:** The non-cellular material produced and secreted by cells into the extracellular space; a major component of connective tissues like bone.
- **Facial Bones:** The 14 bones that form the face, attached to the front of the cranium.
- **False Ribs:** Ribs 8-12, which do not connect directly to the sternum.
- **Femur:** The thigh bone, the largest bone in the human body.
- **Fibrocartilage:** A strong, tough type of cartilage found in intervertebral discs and involved in fracture repair.
- **Fibula:** The smaller, lateral bone of the lower leg; primarily for support, not weight-bearing.
- **Floating Ribs:** Ribs 11 and 12, a special type of false rib that does not connect anteriorly at all.
- **Fontanelles:** Soft spots in a baby's skull, unossified areas of dense connective tissue membranes.
- **Frontal Bone:** The single bone forming the forehead.
- **Girdle:** A ring-like structure of bones that connects the limbs to the axial skeleton (e.g., pectoral and pelvic girdles).
- **Hematoma:** A large blood clot, formed at a fracture site as the first step in bone healing.
- **Hemopoiesis (Hematopoiesis):** The process of blood cell formation, occurring in red bone marrow.
- **Herniated Disc:** A condition where an intervertebral disc bulges out, pressing on spinal nerves (commonly miscalled "slipped disc").
- **Humerus:** The single bone of the arm (brachium).
- **Hyaline Cartilage:** A type of cartilage that forms the initial skeleton of most bones before ossification, and remains in structures like costal cartilage.
- **Hyoid Bone:** A U-shaped bone in the neck, unique for not articulating with any other bone.
- **Hydroxyapatite:** The inorganic mineral component of bone, primarily calcium phosphate, which gives bone its hardness.
- **Ilium:** The largest and most superior of the three bones that fuse to form the os coxa.
- **Intervertebral Discs:** Tough pads of fibrocartilage located between the bodies of adjacent vertebrae, providing cushioning and flexibility.
- **Ischium:** The posterior and inferior part of the os coxa, forming the bone that is sat upon.
- **Kyphosis:** An exaggerated posterior curvature of the thoracic vertebral column (hunchback).
- **Lacunae:** Small spaces within the bone matrix where osteocytes reside.
- **Lamellae:** Concentric layers of bone matrix that surround the central canal in an osteon.

- **Lordosis:** An exaggerated anterior curvature of the lumbar vertebral column (swayback).
- **Lumbar Vertebrae:** The 5 largest vertebrae of the lower back, numbered L1-L5; known for large bodies.
- **Mandible:** The lower jawbone.
- **Manus:** Anatomical term for the hand.
- **Marrow:** Soft tissue found within bones; can be red (for hemopoiesis) or yellow (for fat storage).
- **Maxillae:** The two upper jawbones.
- **Medullary Cavity:** The central cavity of the diaphysis of long bones, containing bone marrow.
- **Metacarpals:** The 5 bones of the palm of the hand, distal to the carpals.
- **Metatarsals:** The 5 bones forming the arch of the foot, distal to the tarsals.
- **Occipital Bone:** The single bone forming the posterior and inferior part of the cranium.
- **Occipital Protuberance:** A bump on the occipital bone, generally larger in males.
- **Ossification:** The process of bone formation.
- **Os Coxae:** The two large hip bones that form the lateral and anterior parts of the pelvic girdle.
- **Osteoblasts:** Bone-building cells that produce the bone matrix.
- **Osteoclasts:** Bone-resorbing cells that break down bone matrix.
- **Osteocytes:** Mature bone cells, derived from osteoblasts, responsible for maintaining bone tissue.
- **Osteon:** The basic structural unit of compact bone, consisting of concentric lamellae around a central canal.
- **Parietal Bones:** The two bones forming the superior and lateral walls of the cranium.
- **Patella:** The kneecap.
- **Pectoral Girdle:** The bony structure connecting the upper limbs to the axial skeleton, composed of the clavicles and scapulae.
- **Pedis:** Anatomical term for the foot.
- **Pelvic Girdle:** The bony structure connecting the lower limbs to the axial skeleton, composed of the two os coxae and the sacrum.
- **Phalanges:** The bones of the fingers and toes. (Singular: phalanx)
- **Pronation:** The rotational movement of the forearm where the palm faces posteriorly (or downward if the arm is extended forward).
- **Pubis:** The anterior portion of the os coxa, forming the anterior part of the pelvic girdle.
- **Radius:** The lateral bone of the forearm, involved in pronation and supination.
- **Red Marrow:** Bone marrow responsible for hemopoiesis.
- **Rib Cage:** The bony enclosure formed by the ribs, thoracic vertebrae, and sternum.
- **Sacrum:** A triangular bone at the base of the spine, formed by the fusion of five sacral vertebrae; part of the axial and pelvic girdles.
- **Scapula:** The shoulder blade, part of the pectoral girdle.
- **Scoliosis:** An abnormal lateral curvature of the vertebral column.
- **Skull:** The bony framework of the head, including the cranium and facial bones.

- **Spinal Cord:** A long, delicate structure of nervous tissue extending from the brainstem down the vertebral column.
- **Spongy Bone:** Porous bone tissue, found deep to compact bone, containing marrow and trabeculae.
- **Sternum:** The breastbone, located in the center of the chest.
- **Supination:** The rotational movement of the forearm where the palm faces anteriorly (or upward if the arm is extended forward).
- **Sutures:** Immovable joints found between the bones of the skull.
- **Tarsals:** The 7 bones of the ankle, part of the pedis.
- **Temporal Bones:** The two bones forming the sides and base of the cranium, housing the ear structures.
- **Thoracic Vertebrae:** The 12 vertebrae of the chest region, numbered T1-T12; articulate with the ribs.
- **Tibia:** The larger, medial bone of the lower leg; bears most of the body's weight.
- **Trabeculae:** Tiny, beam-like structures that make up spongy bone, creating a lightweight yet strong scaffolding.
- **True Ribs:** Ribs 1-7, which connect directly to the sternum via their own cartilage.
- **Ulna:** The medial bone of the forearm, forming the hinge joint at the elbow.
- **Vertebrae:** Individual bones that make up the vertebral column. (Singular: vertebra)
- **Vertebral Column:** The spine, a flexible column of vertebrae enclosing the spinal cord.
- **Yellow Marrow:** Bone marrow primarily composed of fat, serving as a site for fat storage.
- **Zygomatic Bone:** The cheekbone.