I. Introduction to the skeletal system

II. Functions of the skeletal system

OBJECTIVE: List and describe the functions of the skeletal system

A. Support
B. Protection
C. Facilitate body movement
D. Storage depot for minerals and homeostasis
E. Hematopoiesis (hemopoiesis)
F. Triglyceride storage in yellow marrow of bones

III. Review of the skeletal system

Reference: Review lab material and Ch. 7

OBJECTIVES: 1) Describe the basic plan of the skeletal system.

2) Use correct terminology to describe skeletal structures and bone making.

3) Give examples of each type of bone making.

4) List, define, and give examples of each of the different classifications of bone (according to shape).

A. Number of bones

1. Child (360 bones) vs. adult (206)

2. See next page “Bones of the Adult Skeleton”—so how can you explain such a great difference in numbers of bones?

B. Divisions of the skeletal system

1. Axial skeleton

2. Appendicular skeleton
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BONES OF THE ADULT SKELETAL SYSTEM:
Text Reference: Chpt.7: Fig. 7.1 & Table 7.1

AXIAL SKELETON (80 Bones)

Skull------------------------------------------ 29 Bones
  Cranium--------------------------- 8
  Face----------------------------- 14
  Hyoid-------------------------- 1
  Ossicles---------------------- 6

Vertebral column-------------------------------- 26 Bones

Thorax------------------------------------------ 25 Bones
  Sternum--------------------- 1
  Ribs------------------------ 24

APPENDICULAR SKELETON (126 bones)

Shoulder girdles (Pectoral Girdle)------------------ 4 Bones
  Clavicle------------------- 2
  Scapula------------------ 2

Upper Extremities--------------------------------- 60 Bones
  Humerus----------------- 2
  Ulna------------------- 2
  Radius------------------ 2
  Carpals--------------- 16
  Metacarpals------ 10
  Phalanges---------- 28

Pelvic Girdle------------------------------------- 2 Bones
  (Each pelvic bone is composed of three fused bones)

Lower Extremities-------------------------------- 60 Bones
  Femur------------------ 2
  Fibula------------------ 2
  Tibia------------------- 2
  Patella------------------ 2
  Tarsals--------------- 14
  Metatarsals------ 10
  Phalanges-------- 28

TOTAL 206 Bones

Now that you’ve had lab—do these sound familiar?

C. Characteristic bone markings: Define and give examples.
1. Two basic types of markings (What is the general function of each?)
   a. Projections (processes)
   b. Depressions, cavities, and openings

2. Processes to which tendons, ligaments and other connective tissues attach
   a. Crest
   b. Epicondyle
   c. Line
   d. Spine (spinous process)
   e. Trochanter
   f. Trochlea
   g. Tubercle
   h. Tuberosity

3. Processes that form joints
   a. Condyle
   b. Facet
   c. Head

4. Depressions, cavities, and openings
   a. Fissure
   b. Foramen
   c. Fossa
   d. Fovea
   e. Meatus
   f. Sinus (paranasal sinus)
   g. Sulcus

5. Other markings and/or structures
   a. Fontanel
   b. Notch
   c. Process
   d. Suture

Review Question: Notice how various structural features of bones (e.g., rounded ends, depressions, rough areas, grooves, and openings) may be related to their specific function. Explain.

C. Classification of bones based on shape and location. Describe each and give examples of each. Note the relationship between compact bone and spongy bone. Text Reference: Ch. 7, and lab exercises
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1. Long bones
   a. Description
   b. Examples

2. Short bones
   a. Description
   b. Examples

3. Flat bones
   a. Description
   b. Examples

4. Irregular bones
   a. Description
   b. Examples

5. Sesamoid bones
   a. Description
   b. Examples

6. Wormian bones (sutural)
   a. Description
   b. Examples

REVIEW QUESTIONS:
- How do sesamoid bones differ from all other bones?
- How are the ossicles and they hyoid alike?

IV. Bone structure Text Reference: Ch. 6
OBJECTIVES:
1) Relate spongy (cancellous) bone and compact (dense) bone to locations in various types of bones.
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2) Identify the structures of a long bone on a diagram as well as on a real skeleton (in lab) and give their functions
3) Compare spongy bone with compact bone on a macroscopic level.

A. Spongy (cancellous) bone vs. Compact bone (macroscopic level)
   1. Bone may be classified as being spongy (cancellous) or compact (dense).
   2. Spongy and compact bone are located in almost every bone of the body.
   3. Location of cancellous and compact bone within bones of the body.

B. Anatomy of a long bone (Fig. 6.1, pg. 173)
   1. Diaphysis (shaft)
      a. Compact or spongy bone?
      b. Medullary cavity (marrow cavity)
      c. What kind of marrow (child vs. adult)
   2. Epiphysis
      a. Function
      b. Compact or spongy bone?
      c. Cartilage
   3. Metaphysis
      a. Epiphyseal plate
      b. Function
      c. Epiphyseal line
   4. Periosteum
      a. Structure
         1) Type of tissue
         2) Two layers of periosteum
         a. 
         b. 
      b. Osteoblasts
      c. 3 functions of periosteum
   5. Endosteum
      a. 
      b. 
   6. Marrow cavity (medulla cavity)
      a. Location
      b. Red marrow
      c. Yellow marrow
      d. Compare the two types of marrow

V. Histology of Bone Tissue (osseus tissue)
OBJECTIVES:
1) Contrast “hardness of bone” to “strength of bone.”
2) Describe the histology of osseous tissue
3) Compare the histology of compact bone and cancellous bone. Identify the various structures of each.

4) Give the functions of each of these structures.

A. Hardness and strength of bone
   1. Hardness due to
   2. Strength due to
   3. Relate this to chicken and vinegar experiment--lab

B. Haversian System (osteon) (Fig. 6.3 pg. 176)
   1. Haversian canal
   2. Lacunae
   3. Osteocyte
   4. Canaliculi
   5. Volkmann’s canal
   6. Lamellae

C. Lamellar systems of compact bone
   1. Haversian system
   2. Outer circumferential system (just under periosteum)
   3. Inner circumferential system (superficial to medullary cavity/spongy bone)
   4. Intermediate (interstitial) system (why the irregularity?)

D. Mineral salts vs. collagenous fibers

E. Cancellous bone (Spongy bone)
   1. Structures
      a. Trabeculae
      b. Marrow
      c. Locations
   2. Blood vessels and nourishment of osteocytes as compared to compact bone

G. Diagram a cross section and a longitudinal section of a long bone. Label all structures. Reference: Figure 6.1 and 6.3 (Know these for lab and lecture!)

VI. Bone Cell Lineage and Hormonal Control

OBJECTIVES:
   1) Diagram and explain bone cell lineage
   2) Describe hormonal control of bone cell differentiation
3) Diagram a negative feedback mechanism for CT and PTH control of bone cell differentiation.

A. Oxygen content determines whether an osteogenic cell differentiates to bone or cartilage.

B. Hormonal stimulation determines osteogenic differentiation to osteoblast and osteocyte or osteoclast.
   1. Parathyroid hormone (parahormone/PTH) stimulates osteoclast formation.
   2. Thyrocalcitonin (calcitonin/CT) stimulates osteoblast/osteocyte formation.

C. Diagram differentiation of an osteogenic cell to either an osteocyte, osteoclast, or chondrocyte. (Refer to Fig. 6.2 page 174 and you will see this as an overhead transparency)

D. Negative feedback mechanism for calcium regulation in blood via Parathyroid hormone (PTH) and Thyrocalcitonin (CT).
   Reference: Read pp. 638-641-Calcitonin and Parathyroid Glands Fig. 18.14.
• **EXPLAIN:** How does calcitriol (remember Vitamin D—integumentary system?) fit into this picture? Add it to your diagram and explain.

**Review Questions:**

• What effect does PTH have on
  --bones
  --the kidney
  --the GI tract
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• What is the NET effect on Calcium blood level?
• What is the NET effect on phosphorus blood level?
• What are the two hormones responsible for regulating blood calcium levels?
• What are the targets of these two hormones?
• What are the responses to these hormones by the respective targets?
• What stimuli cause these hormones to be released (or inhibited)?

• Describe disorders associated with either hyposecretion or hypersecretion of thyrocalcitonin and/or parathormone (parathyroid hormone). Notice: I did NOT say thyroxin!

• EXPLAIN: The thyroid gland plays another role in addition to calcium regulation.

• Be careful: Do not to confuse thyroxin and thyrocalcitonin, the two hormones of the thyroid gland. How do they differ? Why is it important to consider PTH of the parathyroid glands and CT of the thyroid gland together while considering thyroxin as a separate issue?

• DISORDER: Hypoparathyroidism/hypocalcemia and tetany
• DISORDER: Hyperparathyroidism and osteitis fibrosa cystica

POTENTIAL BONUS
• Trousseau Sign (What causes it and what is its clinical significance?)
• Chvostek Sign (What causes it and what is its clinical significance?)

VII. Review of cartilage—much of this was covered in the tissues lab/tissues lecture study guide.
OBJECTIVES:
1) Describe the histology of cartilage and give examples of their locations.
2) Compare and contrast interstitial and appositional growth of cartilage.
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A. Histology (Review tissue notes, Chapter 4 of text, and lab # 3 and #4)
   1. Connective tissue
   2. Chondrocytes vs. chondroblasts
   3. Lacunae
   4. Matrix
      a. chondroitin sulfate
      b. collagenous fibers
      c. elastic fibers
   5. Perichondrium

B. Types of Cartilage (You should know this from lab by now)
   1. Hyaline Cartilage
      a. histological features
      b. “gristle”
      c. most abundant type in humans
      d. articular cartilage
      e. costal cartilage
      f. nasal septum, larynx, trachea
      g. embryonic cartilage
   2. Fibrocartilage
      a. histological features
      b. not as dense as hyaline
      c. functions
      d. locations
   3. Elastic cartilage
      a. histological features
      b. fibers present
      c. “functions
      d. locations

C. Growth of cartilage (Refer to page 129-130 of text)
   1. Interstitial growth (endogenous)
      a. Division of chondrocytes from within cartilage
      b. Childhood and adolescence vs. adult?
   2. Appositional growth (exogenous)
      a. Inner chondrogenic layer of perichondrium
      b. New layer of cartilage laid down beneath perichondrium on surface of cartilage throughout life
      c. Clinical significance for injury to cartilage and repair?

Review Questions:
   1. Contrast the terms chondroblast and chondrocyte.
   2. Describe the disorder: “herniated disc” or “slipped disc.” Refer to Fig. 7.16 p. 213 for structure of an intervertebral disc and for disorder and diagram. See also page 225 of text. Note also compressed disc (Fig.7.16d)
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VIII. Bone Development

OBJECTIVES:

1) Define ossification.
2) Outline the steps involved in “intramembranous” ossification.
3) Outline the steps involved in “endochondral” ossification.
4) Contrast intramembranous and endochondral ossification.
5) Summarize the “ossification timetable” noting highlights of ossification.

A. Osteogenesis (ossification)

1. Formation of bone
2. Two types of ossification based on sites of ossification.
   a. Intramembranous ossification:
   b. Endochondral ossification:

3. In either type of ossification bone is formed and the bone will have both spongy and compact bone components.

4. It will be helpful to outline the two types of ossification on your own!!!!

B. Intramembranous Ossification (Read text and review figure 6.5, Page 179)

1. Simplest, most direct method of ossification
2. Bones that develop, in layers of connective tissue
3. Flat bones of roof of skull and mandible
4. During embryonic development sheetlike masses of connective tissue membranes appear in sites of future bones
5. Clusters of osteoblasts become active within these membranes
6. Centers of ossification form
7. Calcification occurs
8. Spongy bone tissue is produced in all directions within membranes
   a. lacunae
   b. trabeculae
   c. osteocytes
   d. red marrow
9. The outer layer of cells of the connective tissue membrane gives rise to the periosteum on the outside of the bony structure while osteoblasts on the inside of the membrane (now periosteum) form a layer of compact bone over the surface of the newly built spongy bone.

C. Endochondral Ossification (Figure 6.6, pg 180 - draw it before lecture and study it carefully. Know this!)

1. Replacement of cartilage by bone (cartilage does NOT "change" into bone).
2. Responsible for most of skeletal development, growth of bones and fracture repair.

Revised Fall 2005
3. Hyaline cartilage acts as the cartilaginous model. (Review interstitial and appositional growth of cartilage).

4. Perichondrium covers the cartilaginous model.

   **Note: Several things occur simultaneously—so the order may differ slightly from the text.**

5. In the region of the diaphysis:
   a. Cartilage cells hypertrophy (enlarge), degenerate, then disappear leaving spaces in the diaphysis.
   b. There is an invasion of blood vessels into the spaces left by the disappearing cartilage cells.
   c. Osteogenic bud composed of blood capillaries and osteogenic precursors result.
   d. Osteoblasts move in along with the blood vessels and begin to secrete the organic components of bone.
      1. Collagenous fibers and calcium salts are deposited.
      2. Blood vessels continue to grow through developing bone.
      3. Trabeculae are formed and are loosely joined into spongy network forming spongy bone.
   e. This region of bone formation is the primary ossification center and osseous tissue develops from it toward the ends of the cartilaginous mode.
   f. Destruction of cartilage continues in adjacent regions.
   g. By the 4th month of embryonic development most primary ossification centers have appeared.
   h. The perichondrium becomes the periosteum due to mesenchymal cells becoming osteoblastic.

6. Meanwhile, at the same time and also occurring in this region:
   a. Osteoblasts just below the periosteum deposit a thin layer of compact bone forming the bone collar.
   b. The bone collar continues to develop along the length of bone.
   c. As endochondral ossification extends to the epiphyses, resorption of spongy bone by osteoclasts occurs, forming the medullary cavity.
   d. The cavity fills with red marrow.

7. The epiphyses remain cartilaginous and continue to grow (interstitial-length vs. appositional-width)

8. Later (after birth to 5 years) secondary ossification centers appear in the epiphyses.
   a. Spongy bone formation occurs in all directions from the epiphyseal secondary ossification centers and marrow forms in
spaces of spongy bone.
b. Epiphyseal plate, disc or metaphysis is the region between the
primary ossification center in diaphysis and the secondary
ossification center in epiphysis.

9. The epiphyseal plate allows for growth in length until the "epiphyses
close," that is, the epiphyseal plate has been replaced by bone. This
results in the epiphyseal line.

10. Some cartilage remains on articulating surface (articular cartilage).

OSSIFICATION TIMETABLE

<table>
<thead>
<tr>
<th>Age</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th month- Embryonic Development</td>
<td>Most primary ossification centers have appeared in diaphyses.</td>
</tr>
<tr>
<td>Birth ---- 5 years</td>
<td>Secondary ossification centers appear in epiphyses.</td>
</tr>
<tr>
<td>5 - 12 years (females)</td>
<td>Ossification spreading rapidly from ossification centers and various bones</td>
</tr>
<tr>
<td>5 - 14 years (males)</td>
<td>becoming ossified.</td>
</tr>
<tr>
<td>17 - 20 years</td>
<td>Bones of upper limbs and scapulae become completely ossified.</td>
</tr>
<tr>
<td>18 - 23 years</td>
<td>Bones of lower limbs and coxae completely ossified.</td>
</tr>
<tr>
<td>23 - 25 years</td>
<td>Bones of sternum, clavicles, and vertebrae become completely ossified.</td>
</tr>
<tr>
<td>By 25 years</td>
<td>Nearly all bones are completely ossified.</td>
</tr>
</tbody>
</table>

Review Questions:

1. Very simply, what is the basic difference between intramembranous and
   endochondral ossification?

2. Whether one is describing intramembranous or endochondral ossification,
cartilage is changing into bone. (True or False) Explain your answer.
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IX. Bone Growth

Objectives:
1) Describe the epiphyseal plate of a long bone as it is related to bone growth.
2) Briefly outline how bone grows in length and width.
3) Explain how injury to the epiphyseal disc in a child's bone may seriously interfere with the growth of the bone.
3) Describe factors affecting bone growth

A. Cartilaginous cells of the epiphyseal plate are arranged in four layers. These begin at the epiphysis and extend to the diaphysis.
   1. Zone of reserve/resting cartilage (resting cells).
   2. Zone of proliferating cartilage (young cells undergoing mitosis).
   3. Zone of hypertrophic cartilage (older cells left behind).
   4. Zone of calcified matrix (dead cells and calcified intercellular substance).

B. Ossification zone
   1. Chondroclasts resorb cartilage cells.
   2. Osteoclasts break down intercellular substance nearest diaphysis.
   3. The osteoblasts deposit osseous tissue in place of calcified cartilage.

C. Growth in length of a long bone
   1. Continues to grow in length while cartilaginous cells of epiphyseal disc continue to reproduce.
   2. Stops growing when ossification centers of diaphysis and epiphysis come together and epiphyseal disc becomes ossified.

D. Growth in width of a long bone
   1. Occurs simultaneously with growth in length.
   2. Compact bone is laid down on outside (beneath periosteum).
   3. Spongy bone in diaphysis is broken down due to osteoclast activity under the endosteum.
   4. Marrow cavity forms.

E. Hyaline cartilage remains as articular cartilage.

F. Injury to epiphyseal disc of child.
   1. May permanently retard or stop growth in length of bone
   2. If growth continues it may be uneven.
   3. Sometimes epiphyses may be altered surgically in order to equalize bone growth in bones growing at very different rates.

G. Describe factors that affect bone growth: Read pp. 181-182.
H. How does stress (e.g., weight bearing, exercise, etc.) affect the size of bones? By contrast, what effect do you think weightlessness (e.g., astronauts in space) would have on the size of bones? (Refer to pp. 188-189 of text—this is important!)

Continue with Disorders of the skeletal system—the next study guide.