

OSTEOGENESIS/FUNCTIONAL ANATOMY BONE

GROWTH AND DEVELOPMENT OF THE SKELETON

Objective:

The participant is expected to understand, and be able to describe, the structure of the skeleton at any time in the life cycle: growth (embryogenesis --> ~20), maintenance (~20 --> 40), atrophy (40--> death).

Comment:

The clinical role of the orthopaedic surgeon is problem definition and management. The basic science course content will demonstrate the process of clinical, radiological, and pathological correlation, through clinical examples from the categories of disease (vascular, infectious, mechanical (traumatic), immune, neoplastic/neuropathic). Disease processes alter structure through the mechanisms operant through growth and development, as outlined in the content, effected at a cellular level. Cell biology focused on genetic and molecular mechanisms that foster understanding at a sub-cellular level and will be referred to throughout.

Content:

1. Basic concepts regarding bone:
 - a. The growth, development, remodeling, and maintenance of bone and joints depends on a normal balanced relationship between the following factors: mechanical (stress), metabolic, and circulatory. Because the primary role of the skeleton is mechanical, this factor tends to be predominant.
 - b. The density of bone structure (gross anatomy), is reflected in the radiograph. Change in bone density can be linked to shifts in the balance between the factors listed in 1.
 - c. Bone consists of living cells, the osteocytes, contained in an inorganic fabric which consists primarily of osteoid, calcium hydroxyapatite crystals and important trace elements.
 - d. Osteoid, and thus bone, can only be made by the **osteoblast** (see video <https://www.youtube.com/watch?v=lqcBdaStVro&list=PLefzQtmr3IQ8B4V1Jh1WyQJqHEVyQIfi3&index=3>) --
 1. pathway of collagen 1 formation.
 - e. Types of bone formation: the 3D structure of bone is formed on a template
 - i. woven bone – collagen 1 (also called intramembranous)
 - ii. enchondral -- calcified cartilage
 - iii. lamellar -- pre-existing bone or calcium hydroxyapatite.
 - f. During the process of bone formation, 9 out of 10 osteoblasts undergo apoptosis, while the remaining cell becomes incorporated in stages into the newly formed osteoid as a resident **osteocyte** (see video), a bone cell housed in a lacuna, sending slender cytoplasmic processes that make contact with the processes of adjacent osteocytes.
 - g. Bone deletion can be –

- i. cellular, effected only by the **osteoclast (see video <https://www.youtube.com/watch?v=NPzm1nGA7DI&list=PLefzQtmr3IQ8B4V1JhlWyQJqHEVyQIfi3&index=4>)** or,
 - i. chemical, in 2 processes –
 - a. dissolution around dying osteocytes (oncosis) and,
 - b. mineral exchange related to acid/base metabolism through the massive surface area of bone (lacunae, canaliculi, vascular canals, and endosteal).
- 2. Wolff's law: bone is laid down as needed, and deleted where it is not needed, as demonstrated through the clinical example of a proximal tibial bone tumor.
 - a. Core Concept: reactions in bone are linked to a cellular dynamic between bone formation and deletion, effected by osteoblasts and osteoclasts, and are reflected by changes in bone density.
- 3. Embryogenesis:
 - a. limb bud development
 - b. primary center of ossification
 - c. initial development of a long bone
 - d. joint structure; link between radiograph and cellular structure
 - e. circulation in a long bone:
 - i. central intramedullary (nutrient artery)
 - ii. metaphyseal
 - iii. epiphyseal
 - iv. periosteal
 - f. growth plate; growth in length, morphology:
 - i. resting
 - ii. proliferation/secretion
 - iii. hypertrophy/secretion
 - iv. senescence/death
 - v. primary trabecular formation
 - vi. remodeling
 - g. metaphyseal formation/modeling
 - h. diaphyseal formation/modeling
 - i. cambium layer of the periosteum
 - ii. woven bone
 - iii. passive (primary) osteons
 - iv. bone remodeling unit/secondary osteon formation
 - v. cortical blood circulation
 - i. Secondary center of ossification
 - j. Growth plate closure
- 4. Development of the adult skeleton/modeling/remodeling/aging and attrition

OSTEOGENESIS YOUTUBE VIDEO SERIES

- Learning Bone Growth – 1 Bone Formation – Background Concepts
- Learning Bone Growth – 2 The Osteoblast and Woven Bone Formation

- Learning Bone Growth – 3 The Osteoclast
- Learning Bone Growth – 4 The Osteocyte
- Osteogenesis 1 – Basic Concepts
- Osteogenesis 2 – Circulation
- Osteogenesis 3 – Development of a Long Bone
- **Osteogenesis 4 – Growth Plate Structure and Function- NYP**
- Osteogenesis 5 – Completion of Adult Bone Structure

NYP = not net posted (in preparation)

The concepts are those developed by Drs Lent Johnson, and Don Sweet. Dr. Sweet provided a document, ***Skeletal Radiologic / Pathologic Correlation*** that organizes the concepts well, and adds a primer linking radiographic images to the underlying morphology (**URL NYP**). Reading this will provide a concise summary of the concepts outlined in the videos.

H & E images were from the Armed Forces Institute of Pathology Collection.

The videos were produced by Dr. Thomas V. Smallman