Biomechanics of Human Bone Growth and Development

Stiffness & Compressive Strength

- **Stiffness**
  - Stress/strain in a loaded material
  - Stress divided by the relative change in shape

- **Compressive Strength**
  - Ability to resist compression

Calcium

- Calcium carbonate
- Calcium phosphate

*Contribute to stiffness and compressive strength in bone*

Collagen

- Contributes to flexibility and tensile strength in bone
- Collagen is progressively lost with age
- Loss of collagen causes bone brittleness

Other Factors Effecting Bone Strength

- **Water Content**
  - Usually comprises 25%-30% of bone weight

- **Bone Porosity**
  - Amount of bone volume filled with pores or cavities

Bone Categories: *based on porosity*

- **Cortical Bone**
  - Compact mineralized bone
  - Low porosity
  - Found in shafts of long bones

- **Trabecular Bone**
  - Aka cancellous or spongy bone
  - Less compact
  - High porosity
  - Found in the ends of long bone and vertebrate
Bone Structure: *typical long bone*

- Endosteum
- Cortical bone
- Marrow
- Periosteum
- Trabecular bone
- Cortical bone

Proximal epiphysis
- Epiphyseal plate
- Trabecular bone

Diaphysis
- Nutrient artery
- Medullary cavity

Distal epiphysis
- Epiphyseal plate

Effects of Bone Porosity

- Cortical bone can withstand more stress but less strain
  - Less porous
- Trabecular bone can undergo more strain before fracturing
  - More porous

Structure Effects Strength

- Bone is anisotropic
  - Bone has different strength and stiffness depending on direction of the load
- Bones are unique to each individual

Axial Skeleton

- Skull
- Vertebrate
- Sternum
- Ribs

Appendicular Skeleton

- Bones Composing the body appendages
  - Shoulder Girdle
  - Upper Extremities
  - Pelvic Girdle
  - Lower extremities

Bone Types

- Short Bones
- Flat Bones
- Irregular Bones
- Long Bones
Short Bones
- Approximately cubical
  - Carpals
  - Tarsals

Flat Bones
- Protect organs
  - Provide surface for muscle attachments
    - Scapulae
    - Sternum
    - Ribs
    - Patellae
  - Some bones of the skull

Irregular Bones
- Have different shapes to serve different functions
  - Vertebrate
  - Sacrum
  - Coccyx
  - Maxilla

Long Bones
- Framework of the appendicular skeleton
  - Humerus
  - Radius
  - Ulna
  - Femur
  - Tibia
  - Fibula

Epiphyseal Plates
- Growth Centers allowing bones to grow in length
- New bone cells are produced by osteoblasts until plate closure

Bone Growth in Circumference
- Inner layer of the periosteum builds concentric layers of new bone on top of existing bone
  - Osteoblasts
    - Build new bone tissue
  - Osteoclasts
    - Resorb old bone tissue
Training Bones???
- Bones respond to training… and or lack of training
- According to Wolff’s Law
  - Densities
  - Sizes
  - Shapes
  Are determined by the magnitude and direction of forces

Wolff’s Law
- Osteoblasts and osteoclasts are continually building and resorbing bone
- Increases and decreases in stress influence osteoblast/osteoclast activity

Increasing Bone Density
- Weight Bearing Exercise

Diminishing Bone Density
- Lack of weight bearing exercise
- Spending excessive time in water
  - Bed Rest
  - Space Travel

Osteoporosis
- Disorder involving decreased bone mass and strength
- Can result in:
  - Pain
  - Fractures
  Due to daily activities

Osteoporosis Effects
- Type I
  - Postmenopausal
  - Affects 40% of women after age 50
- Type II
  - Age-associated
  - Affects most men and women after age 70
- Female Athlete Triad
  - Disordered eating
  - Amenorrhea
  - osteoporosis
Prevention and Treatment of Osteoporosis

• Regular weight bearing exercise
• Postmenopausal women hormone replacement
• Adequate dietary calcium and vitamin D
• Avoid
  – Smoking
  – Excessive protein consumption
  – Caffeine
  – Alcohol