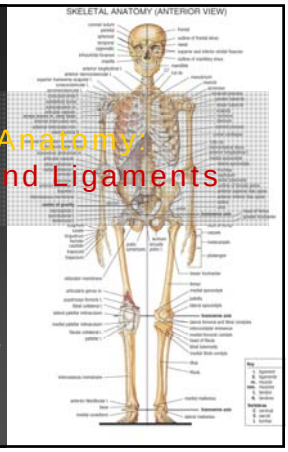
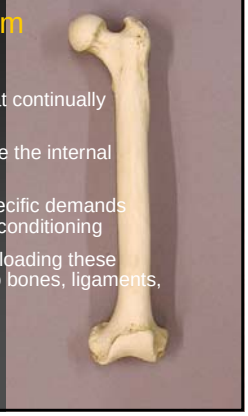
Skeletal System Anatomy: Bones, Joints and Ligaments

Scott Riewald
United States Olympic Committee



The Skeletal System

- Bone is dynamic with living cells that continually remodel bone tissue
- Bones of the skeletal system provide the internal framework of the body
- Responds through adaptation to specific demands placed upon it through training and conditioning
- Specific protocols of loading and unloading these tissues cause unique adaptations to bones, ligaments, tendons, and cartilage.



Function of the Skeletal System

- **Structure and protection**
- **Movement**
- **Blood cell production**
  - **Spongy bone houses the red marrow that produces blood cells**
  - **The production of red and white blood cells is a result of differentiation of mature blood stem cells which reside primarily in the flat bones of the skull, ribs, sternum, and the ends of the long bones.**
  - **Every second, the body produces over 2 million RBCs**

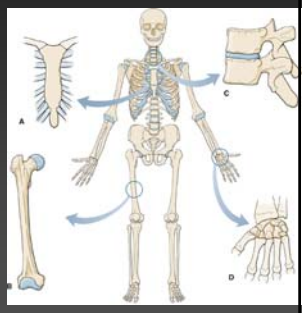
Types of Bones

a. Flat bones
- Sternum, ribs, skull

b. Long bones
- Femur, tibia, humerus

c. Irregular bones
- Vertebrae, maxilla

d. Short bones
- Carpals, tarsals



Bone Cells - Osteocytes

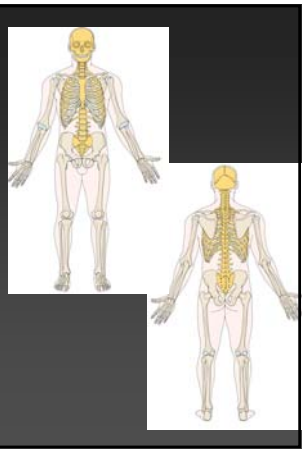
- Osteoclasts – reclaim calcium or damaged bone

- Osteoblasts – deposit matrix of new bone

Both responsible for remodeling that can occur with training and skeletal loading.

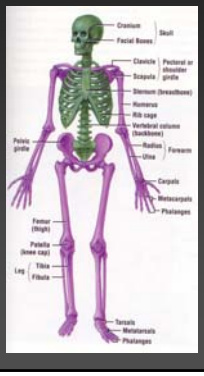
Axial Skeleton

- Skull
- Vertebral column
- Sacrum
- Coccyx
- Ribs
- Sternum



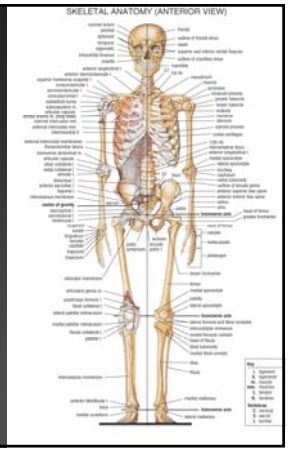
Appendicular Skeleton

- **Shoulder Girdle**
  - ✓ Clavicle
  - ✓ Scapula
- **Arm Bones**
- **Pelvic Girdle**
  - ✓ Pelvic bones
- **Leg Bones**



Skeletal Anatomy: Bones to Know

- Skull
- Clavicle
- Humerus
- Radius
- Ulna
- Carpals
- Metacarpals
- Phalanges
- Ribs
- Sternum



Skeletal Anatomy: Bones to Know

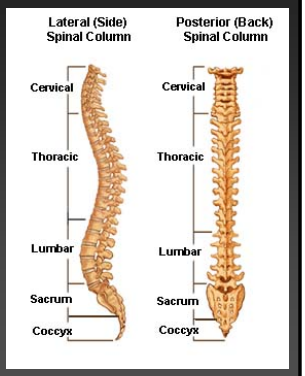
- Scapula
- Pelvis – illium, pubis
- Femur
- Tibia
- Fibula
- Patella

Bones of the Foot

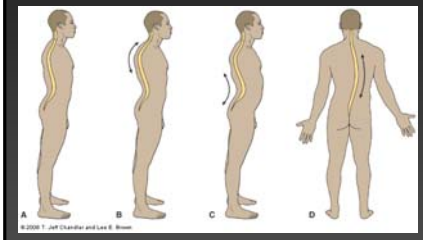
- Talus
- Calcaneous
- Metatarsals
- Phalanges

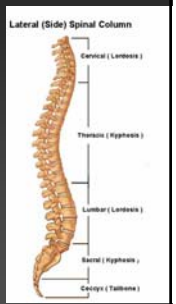
Spinal Column

- Cervical Spine
  - 7 vertebrae
- Thoracic Spine
  - 12 vertebrae
- Lumbar Spine
  - 5 vertebrae
- Sacrum
  - 5 fused vertebrae
- Coccyx
  - 4 fused vertebrae



Curvature of the Spine





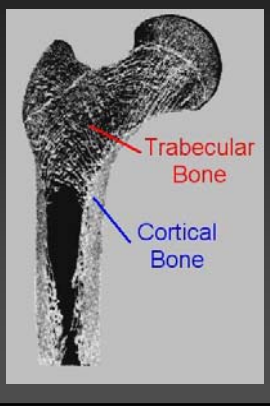
Lordosis – "inward" curvature of the spine

Kyphosis – "outward" curvature of the spine

Scoliosis – lateral curvature of the spine

Types of Bone

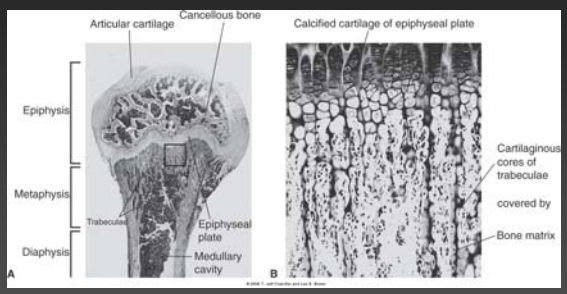
- **Cortical Bone:**
  - Highly mineralized
  - Dense
  - Shafts of long bones
  - Outer layer at ends
  - Smaller bones
- **Trabecular Bone:**
  - Less mineralized
  - More porous
  - Bone ends



Growth Plates – Epiphyseal Plates

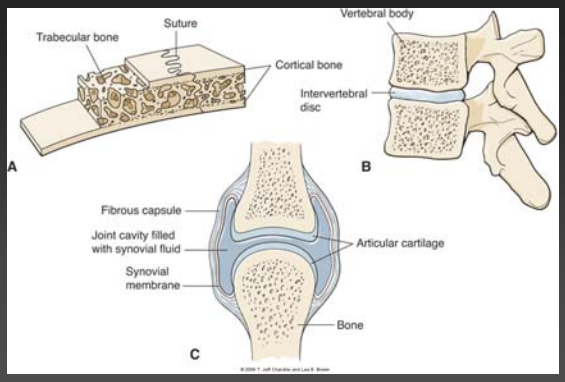
- Site of bone growth
- Long bones can continue to grow until closure of plates.
- Risk of injury

Primary Bone Growth at Epiphysis



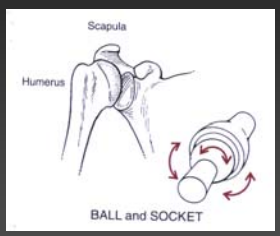
Joint Classifications

- **Fibrous/ Synarthrosis** (immoveable)
  - Dense connective tissue/ collagen
  - e.g. Skull sutures, distal radio-ulnar, pelvis
- **Cartilagenous/ Amphiarthrosis** (partially moveable)
  - Connected by cartilage
  - e.g. ribs
- **Synovial/ Diarthrosis** (freely moveable)
  - Have a joint capsule/ bursa with synovial fluid
  - Most joints in the body



Synovial: Ball and Socket Joint

- Movement in three planes
  - Flexion/ extension
  - Abduction/ adduction
  - Rotation
- Most mobile
- Examples:
  - Hip and shoulder joints

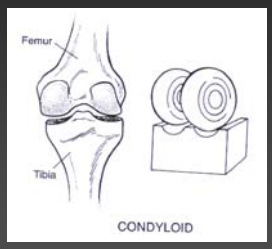


Synovial: Hinge Joint

- Movement in one plane
  - Flexion/ extension
  - Uniaxial
- Examples:
  - Interphalangeal joints of foot and hand
  - Ulnohumeral joint at the elbow.

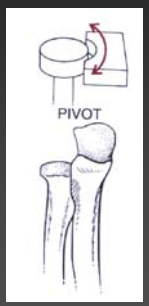
Synovial: Condyloid Joint

- Movement primarily in one plane with small amounts of movement in another plane
  - Flexion/ Extension
  - Rotation
- Examples:
  - Knee joint



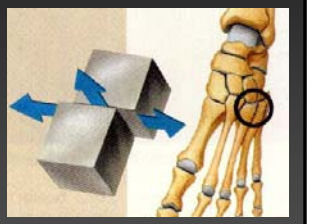
Synovial: Pivot Joint

- A ring of bone and ligament surrounds the surface of the other bone
- Uniaxial movement in one plane
  - Rotation
  - Prontation/ supination
- Examples:
  - Between cervical vertebrae 1 & 2 (atlanto-axial articulation)
  - Proximal radio-ulnar joint
  - Distal radio-ulnar joint



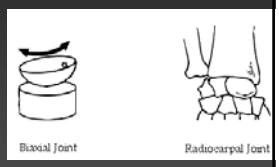
Synovial: Gliding Joint

- Movement does not occur about an axis and is termed non-axial since it consists of two flat surfaces that slide over each other to allow movement.
- Examples:
  - Between tarsal bones in foot -
  - Between carpal bones in hand



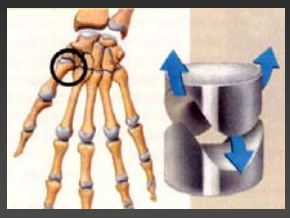
Synovial: Ellipsoid Joint

- Allows movement in two planes
  - Flexion/ extension
  - Abduction/ adduction
  - Biaxial.
- Examples
  - radiocarpal articulation at the wrist
  - metacarpophalangeal articulation in the hand



Synovial: Saddle Joint

- Only at the carpometacarpal articulation of the thumb
- Two planes of motion
  - Flexion/ extension
  - Abduction/ adduction
  - Small amount of rotation also allowed.
- Similar to the ellipsoid joint in function.



Wolff's Law

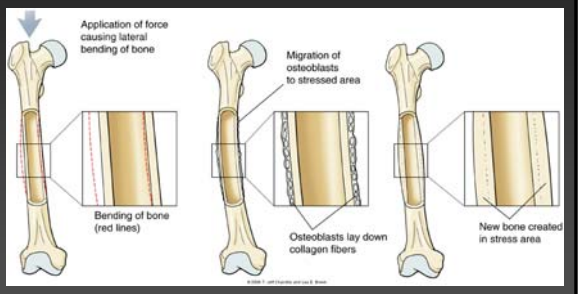
"The densities, and to a lesser extent, the sizes and shapes of bones are determined by the magnitude and direction of the acting forces applied to bone."

Specificity - The body will adapt to the stresses placed upon it – as long as those stresses are reasonable and not excessive.

Minimal Essential Strain (MES)

- Minimum volume and intensity of loading required to cause an increase in bone density
- Approx. 10% of the strain required to fracture bone is considered the threshold at which new bone formation is triggered
- What's the process?
  - Strain triggers 'bone activation' remodeling
  - Osteoclasts remove 'damaged bone' – 1 to 3 weeks
  - Shut down of osteoclasts, switch to osteoblasts – 1 to 2 weeks
  - New bone formation – total time 3½ months

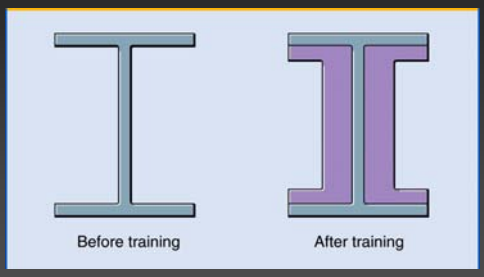
Skeletal Adaptation to Stress



Appropriate Training Stimuli

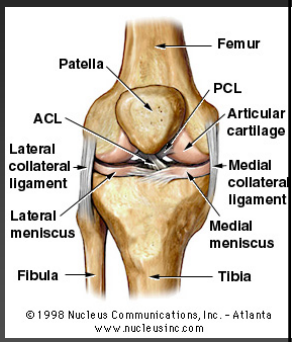
- 'Dynamic loading' – rapid loading
  - Axial loading/ higher impact forces
- Higher Frequency loading
- Directional specificity
  - Small gains in bone density can produce large strength improvements
- More, shorter workouts as opposed to longer ones
  - Takes 6-8 hours for bone to recover ability to lay down new bone

Skeletal Adaptations to Loading



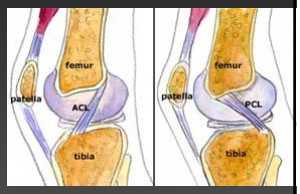
Ligaments

- Fibrous tissue
- Connects bone to bone
- Stabilizes joint
  - Restrict or limit movement to certain planes
  - Also 'fix' one bone to another (e.g. acromio-clavicular joint)



Major Ligaments in Knee

- ACL - Anterior cruciate ligament
  - Keeps tibia from moving forward
- PCL - Posterior cruciate ligament
  - Keeps tibia from moving backwards
- MCL - Medial collateral ligament
- LCL - Lateral collateral ligament

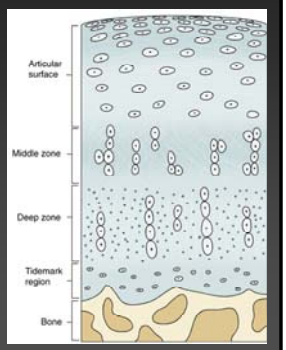


Articular Cartilage

- Covers ends of long bones
- Made of collagen, water, stiff gel-like substance, proteoglycans
- Provides smooth surface (low friction) under pressure
- Osteoarthritis

Cartilage Layers

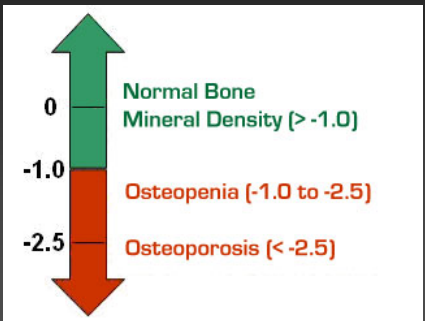
1. The articular surface, which is super slick
2. The mid-zone composed of collagen fibrils and fluid swollen proteoglycans
3. The deep zone layer
4. The tidemark region where the cartilage matrix meshes with the actual bone structure



Skeletal Health - Osteoporosis

- Loss of bone density
  - Postmenopausal women
  - Men and women >70
  - Young athletes with eating disorder (e.g. anorexia)
- Higher bone density in 'active years' leads to higher bone density later in life
- Female athlete triad
- DEXA scan

DEXA Bone Mineral Density Scan



The Female Athlete Triad