Skeletal Tissue

- The skeleton consists of approximately **20% of total body weight**
- The skeletal system is generally broken down into axial and appendicular skeletons.
- The skeletal framework determines shape and body size.
- While one can roughly **predict adult height by doubling the height of a 2-year-old**,
- The skeletal system and frame can be greatly influenced by nutrition, activity level, and postural habits.

Skeletal alteration

- A common example of skeletal alteration in the immature skeleton is **idiopathic scoliosis**, a lateral curvature in the spine, present in approximately 15 to 20% of girls aged 10 to 12years.
- It is termed idiopathic because of the forces causing the lateral curve have not been identified.
- Is it because young girls spend too much time weight bearing on one limb? Is it related to posture that includes hyperextended knees and swayback?
- It is easy to speculate on possible causes, but the scientific substantiation of this disorder still evades us.
- We do know that the skeletal system can be shaped and formed through activity
- It is important to understand how the skeletal system responds in order to institute programs that will promote skeletal health and prevent skeletal injury.

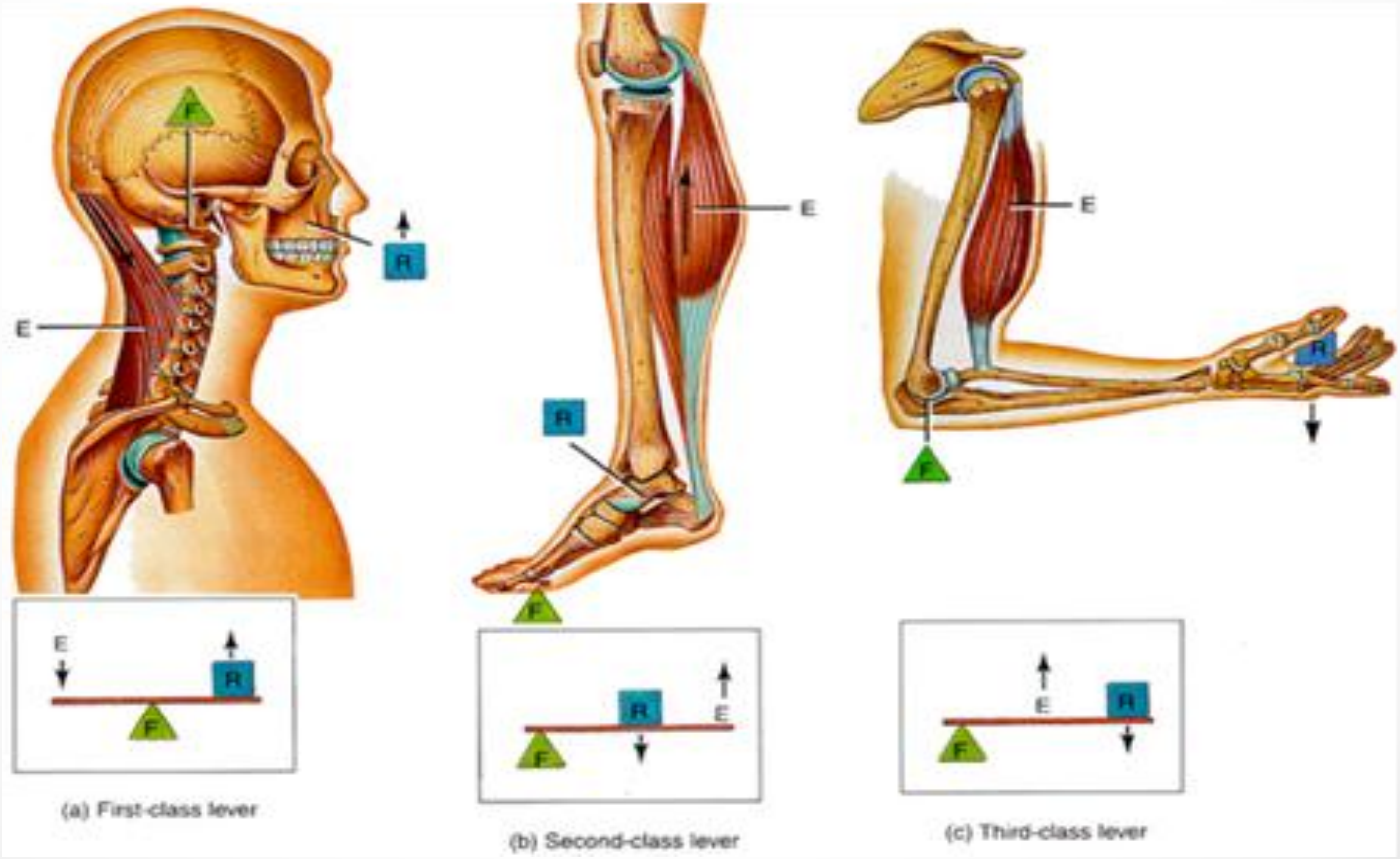
Functions of the skeletal system

- The skeletal system performs many functions: leverage, support, protection, storage, and blood cell formation. Two of these functions, leverage and support, are critically important for human movement.

Levers

- The skeletal system provides the levers and axes of rotation about which the muscular system generates the movements.
- A lever is a simple machine that magnifies the force and/or speed of movement.
- The levers are primarily the long bones of the body, and the axes are the joints where the bones meet .

Classes of levers



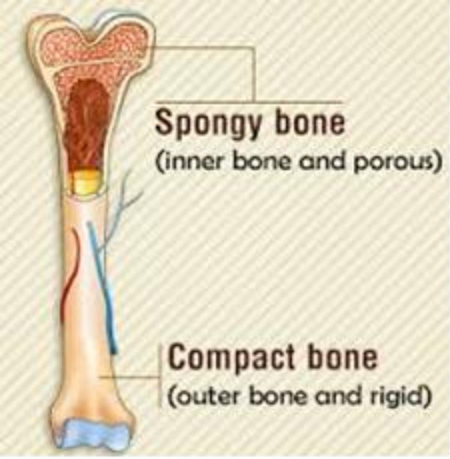
Support

- A second important function of the skeletal system is the provision of a support structure.
- The skeleton can maintain a posture while accommodating large external forces, such as those involved in jumping.
- The bones increase in size from top to bottom in proportion to the amount of body weight they bear; **thus, the bones of the lower extremity and the lower vertebrae and pelvic bones are larger than their upper extremity and upper torso counterparts.**
- A visual comparison of the humerus and femur or the cervical vertebrae and lumbar vertebrae demonstrates these size relationships.

Architecture of bone

- Bone is composed of a matrix of inorganic salts and connective tissue referred to as collagen fibers.
- Bone cells are referred to as **osteocytes**.
- The two types of these cells are referred to as **osteoblasts and osteoclasts**. These cells are responsible for remodeling bone.
- **Bone is composed of two types of osseous, or bone tissue: cortical bone and cancellous bone .**
- **The hard outer layer is compact bone; internal to this is spongy bone.**
- The architectural arrangement of bony tissue is remarkably well suited for the mechanical demands imposed upon the skeletal system during physical activity.

Architecture of bone



Cortical bone

- consists of a system of hollow tubes called lamellae that are placed inside one another. Lamellae are composed of collagen fibers, all running in a single direction.
- The collagen fibers of adjacent lamellae always run in different directions.
- A series of lamellae form an osteon or caversian system.
- ***Osteons* are pillar-like structures that are oriented parallel to the stresses that are placed on the bone.**
- **The arrangement of these weight-bearing pillars and the density of the compact bone provide strength and stiffness to the skeletal system.**
- **Cortical bone can withstand high levels of weight bearing or muscle tension in the longitudinal direction before fracture.**

Cortical bone

- This type of is especially capable of absorbing tensile loads if the collagen fibers are parallel to the load.
- Typically, the collagen is arranged in layers running in longitudinal, circumferential, and oblique configurations.
- This offers resistance to tensile forces in different directions, because the more layers there are, the greater the strength and stiffness the bone will have.
- Also, where muscles, ligaments, and tendons attach to the skeleton, the collagen fibers are arranged parallel to the insertion of the soft tissue, thereby offering greater tensile strength for these attachments.
- A thick layer of compact bone is found in the shafts or long bones, where strength is necessary to respond to the high loads imposed down the length of the bone, during weight bearing or in response to muscular tension.
- Thin layers of compact bone are found on the ends of the long bones, the epiphyses, and also covering the short or irregular bones.

Cancellous bone

- The bone tissue interior to the cortical bone is referred to as cancellous or spongy bone. This bone has lattice-like structure with a porosity greater than 70%. Cancellous bone structure, although quite rigid, is weaker and less stiff than the compact bone. The small, flat pieces of bone making up the spongy bone are called trabeculae.
- The trabeculae adapt to the direction of the imposed stress on the bone, providing strength without adding much weight.
- Collagen runs along the axis of the trabeculae, providing cancellous bone with both tensile and compressive resistance.

- The high porosity gives spongy bone high-energy storage capacity, so that this type of bone becomes a crucial element in energy absorption and stress distribution when loads are applied to the skeletal structure.
- Cancellous bone is not as strong as compact bone, and there is a high incidence of fracture in the cancellous bone of the elderly.
- This is believed to be caused by loss of compressive strength due to mineral loss.

Biomechanical Characteristics of Bone:

Bone tissue Constitution

- Osseous tissue is strong and one of the body's hardest structures because of its combination of inorganic and organic elements.
- The minerals, calcium and phosphate, along with collagen, constitute the organic element in one and make up approximately 60 to 70% of bone tissue.
- Water constitutes approximately 25 to 30% of the weight of bone tissue.

- Bone characteristics

  -Bone tissue is a viscoelastic material whose mechanical properties are affected by its deformation rate.
  -The ductile properties of bone are provided by the collagenous material in bone.
  -The collagen content gives bone the ability to withstand tensile loads.
 -Bone is also brittle, and its strength depends on the loading mechanism.
 -The brittleness of bone is provided by the mineral constituents that provide bone with the ability to withstand compressive loads.

Resorption and deposit of bone

- Bone is a highly adaptive material that is very sensitive to tissue, immobilization, or vigorous activity and high levels of loading.
- Bone tissue is self-repairing and can alter its properties and configuration in response to mechanical demand.
- This was first determined by the German anatomist Julius Wolff, who provided the theory of bone development, termed Wolff's law.
- This law states: "Every change in the form and function of a bone or their function alone is followed by certain definitive changes in their internal architecture and equally definite secondary alternation in their external conformation, in accordance with mathematical laws"

Strength and stiffness of bone

- The behavior of any material under loading conditions is determined by its strength and stiffness. When an external force is applied to a bone or any other material, there is an internal reaction. The strength can be evaluated by examining the relationship between the load imposed (external force) and the amount of deformation (internal reaction) occurring in the material.

Anisotropic characteristics

- Bone tissue is an anisotropic material, which means that the behavior of bone will vary with the direction of the load application.
- In general, tissue of long bones can handle the greatest loads in the longitudinal direction and the least amount of load across the surface of the bone.
- Long bones are stronger withstanding longitudinal loads because they are habitually loaded in that direction.

Viscoelastic response

- Bone is also viscoelastic, meaning that its response depends on the rate at which the load is applied and the duration of the load. At a higher speed of loading, bone can handle greater loads before it fails, or fractures. The bone loaded slowly fractures at a load that is approximately half of the load handled by bone at a fast rate of loading.

Elastic response

- At the onset of loading, bone exhibits a linearly elastic response.
- When a load is first applied, a bone will deform through a change in length or angular shape.
- Bone deforms no more than approximately 3% this is considered in the elastic region of the stress – strain curve because when the load is removed, the bone will recover and return to its original shape or length.
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Plastic response

- With continued loading the bone tissue reaches its yield point, after which its outer fibers begin to yield, with micro tears and debonding of the material in the bone.
- This is termed plastic region of the stress –strain curve.
- The bone tissue begins to deform permanently and eventually fractures if loading continues in the plastic region.
- Thus, when the load is removed, the bone tissue does not return to its original length but stays permanently elongated.

Types of loading of the human skeleton

- The skeletal system is subjected to a variety of applied forces as bone is loaded in various directions.
- Loads are produced by weight bearing, by gravity, by muscular forces, and by external forces.
- The stress and strain produced by forces applied to bones are responsible for facilitating the deposit of osseous material.
- The loads are applied in various directions, producing five types of forces; compression, tension, shear, bending and torsion.

Compression forces

- A compression force presses the ends of the bones together and is produced by muscles, weight bearing, gravity, or other external loading along the length of the bone.
- **The compression stress and strain inside the bone shorten and widen the bone. If large compressive forces are applied, compressive fracture occurs.**
- Compressive forces are responsible for patellar pain and softening and destruction of the cartilage underneath the patella. This injury is known as chondromalecia patellae. As the knee joint moves , the patella moves up and down in the femoral groove. The load between the patella and the femur increases and decreases to reach **peak compressive stress on the lateral surface at 50 degrees flexion and least at full extension.**