Physiology of Skeletal System
"Bone Tissue"

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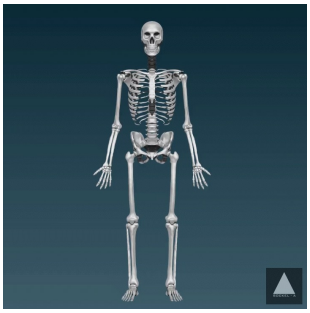

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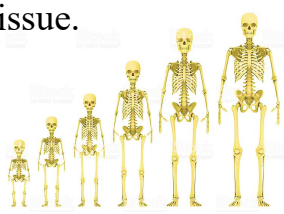
Contents:

- Functions of the skeletal system.
- The factors that affect bone growth & bone remodeling.
- The importance of calcium in bone tissues.
- Explain how blood calcium level is regulated
- Effect of exercise and mechanical stress on bone tissue.
- Describe the effects of aging on bone tissue.



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Objectives:

After studying this lecture, you will be able to:

1. Describe the 6 main functions of the skeletal system.
2. Know the factors that affect bone growth and bone remodeling.
3. Describe the importance of calcium in the body.
4. Explain how blood calcium level is regulated
5. Explain how does exercise affect bone tissues.
6. Describe the effects of aging on bone tissue.

The Skeleton

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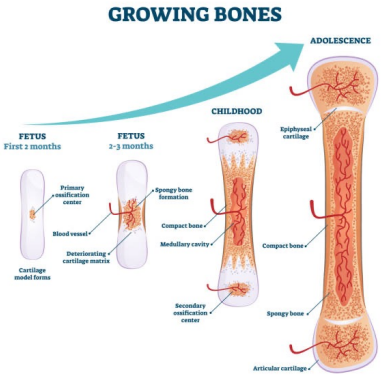
Bone Tissue and Homeostasis:

- Bone tissue is a complex and dynamic living tissue.
- It is continuously:
  - growing,
  - remodeling, and
  - repairing itself.



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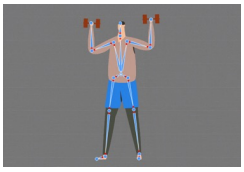
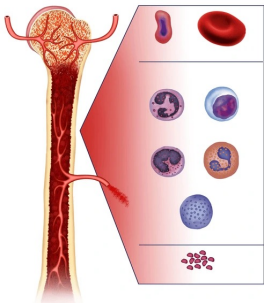
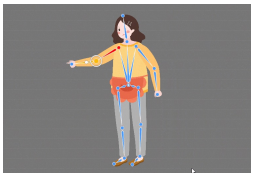
Bone Tissue and Homeostasis:

- **It contributes to homeostasis of the body by:**
  - **providing support and protection,**
  - **producing blood cells,**
  - **storing minerals and triglycerides.**

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Introduction:

- A bone is an organ made up of several different tissues working together:
  - bone (osseous) tissue,
  - Cartilage,
  - Dense connective tissue,
  - Epithelial tissue,
  - Adipose tissue,
  - Nervous tissue.

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Introduction:

- **Skeletal system** is the entire framework of bones and their cartilages.
- **Osteology** is the study of bone structure and the treatment of bone disorders.

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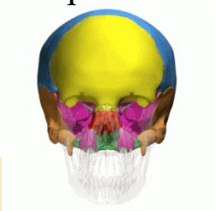
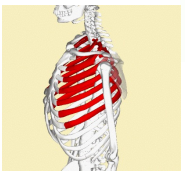
Functions of Skeletal system:

1. **Support:** The skeleton serves as the structural framework for the body by supporting soft tissues and providing attachment points for the tendons of most skeletal muscles.
2. **Protection:** The skeleton protects the most important internal organs from injury. **For example:**



✓ **Cranial bones** protect the brain, and

✓ **Rib cage** protects the heart and lungs.



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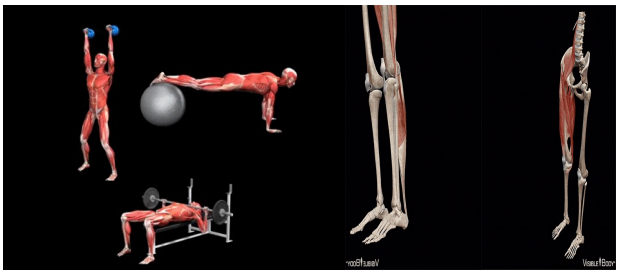
Functions of Skeletal system:

3. Assistance in movement: Most skeletal muscles attach to bones; when they contract, they pull on bones to produce movement.



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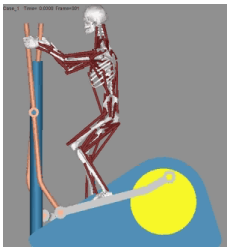
Functions of Skeletal system:

3. Assistance in movement:



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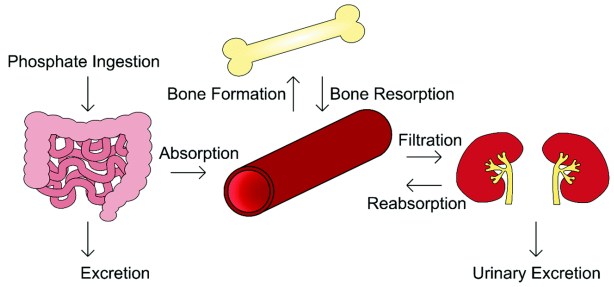
Functions of Skeletal system:

4. **Mineral homeostasis** (storage and release).

- Bone tissue makes up ~18% of the weight of the human body.
- Stores several minerals, especially Ca & P (**strength of bone**). Bone tissue stores ~99% of the body's Ca.
- On demand, bone releases minerals into the blood **to maintain homeostasis**.



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Functions of Skeletal system:

5. **Blood cell production:** Within certain bones, a connective tissue **Red bone marrow** (RBM) produces RBCs, WBCs, and platelets (**Hemopoiesis**).

- **RBM** consists of developing blood cells, adipocytes, fibroblasts, and macrophages within a network of reticular fibers.
- It is present in developing bones of the fetus and in some adult bones, such as the hip bones, ribs, sternum, vertebrae, skull, and ends of the bones of the humerus and femur (thigh bone).

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Functions of Skeletal system:

- In a newborn, all bone marrow is **RED** and is involved in **hemopoiesis**.
- With increasing age, much of the bone marrow changes from red to yellow.
- **Yellow bone marrow** consists mainly of adipose cells, which store triglycerides.
- The stored triglycerides are a potential chemical energy reserve.

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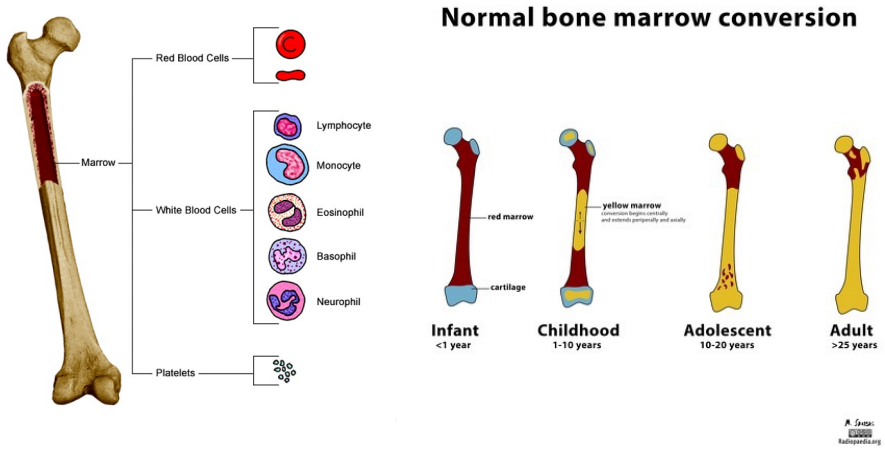

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Remodeling of Bone:

- Like skin, bone forms before birth but continually renews itself thereafter.
- **Bone remodeling** is the ongoing replacement of old bone tissue by new bone tissue. **It involves:**
- **Bone resorption:**
  - removal of minerals and collagen fibers from bone by osteoclasts.
  - results in the **destruction of bone extracellular matrix**.
- **Bone deposition:**
  - **addition** of minerals and collagen fibers to bone by osteoblasts.
  - results in the **formation of bone extracellular matrix**.

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Remodeling of Bone:

- The distal portion of the femur is replaced about every four months.
- By contrast, bone in certain areas of the shaft of the femur will not be replaced completely during an individual's life.
- Even after bones have reached their adult shapes and sizes, old bone is continually destroyed and new bone is formed in its place.
- Remodeling also removes injured bone, replacing it with new bone tissue.
- Remodeling may be triggered by factors such as exercise, sedentary lifestyle, and changes in diet.

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Remodeling of Bone:

- The strength of bone is related to the degree to which it is stressed, if newly formed bone is subjected to heavy loads, it will grow thicker and therefore be stronger than the old bone.
- The shape of a bone can be altered for proper support based on the stress patterns experienced during the remodeling process.
- New bone is more resistant to fracture than old bone.

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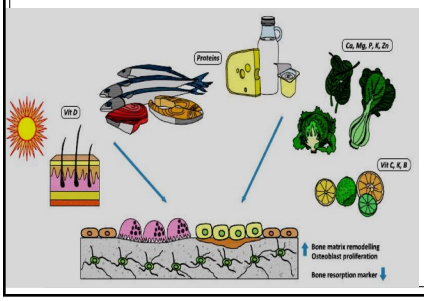
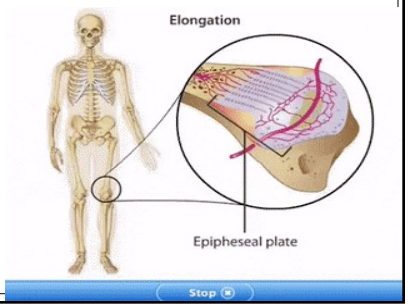
Factors Affecting Bone Growth and Bone Remodeling:

- Normal bone metabolism depends on several factors. These include:
  - Adequate dietary intake of **minerals.**
  - Adequate dietary intake of **vitamins.**
  - Sufficient levels of **several hormones**.





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Factors Affecting Bone Growth and Bone Remodeling:

1. Minerals:

- Large amounts of Ca and P are needed while bones are growing, as are smaller amounts of Mg, F, and Mn.
- These minerals are also necessary during bone remodeling.

2. Vitamins:

- Vitamin A stimulates activity of osteoblasts.
- Vitamin C is needed for synthesis of collagen.
- Vitamin D helps build bone by increasing the absorption of Ca from foods in the gastrointestinal tract into the blood.
- Vitamins K and B_{12} are also needed for synthesis of bone proteins

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Factors Affecting Bone Growth and Bone Remodeling:

3. Hormones:

- During childhood, the hormones most important to bone growth are the insulin-like growth factors (IGFs), which are produced by the liver and bone tissue

- IGFs:
  - Stimulate osteoblasts,
  - promote cell division at the epiphyseal plate and in the periosteum,
  - enhance synthesis of the proteins needed to build new bone.

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Factors Affecting Bone Growth and Bone Remodeling:

3. Hormones: *cont……*

- IGFs are produced in response to the secretion of growth hormone (GH) from the anterior lobe of the pituitary gland.
- Thyroid hormones (T3 and T4) from the thyroid gland also promote bone growth by stimulating osteoblasts.
- In addition, the hormone insulin from the pancreas promotes bone growth by increasing the synthesis of bone proteins.

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Bone's Role in Calcium Homeostasis:

- Bone is the body's major Ca reservoir (storing 99% of total body Ca)
- One way to maintain the level of Ca in the blood is to control the rates of **Ca resorption** from bone into blood and of **Ca deposition** from blood into bone.
- Both nerve and muscle cells depend on a stable level of Ca^{2+} in extracellular fluid to function properly.
- Blood clotting also requires Ca^{2+}.
- Also, many enzymes require Ca^{2+} as a cofactor.
- blood plasma level of Ca^{2+} is 9-11 mg/100 mL.
  - **Cardiac arrest: if the concentration goes too high.**
  - **Respiratory arrest: if the level falls too low.**

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Bone's Role in Calcium Homeostasis:

- The role of bone in Ca homeostasis is to help "buffer" the blood Ca^{2+} level:
  - **Releasing-Ca^{2+} into blood (using osteoclasts) when the level decreases**
  - **Absorbing-Ca^{2+} into blood (using osteoblasts) when the level rises.**
- Ca^{2+} exchange is regulated by hormones, the most important of which is **parathyroid hormone** (PTH) secreted by the parathyroid glands.
- **PTH** increases blood Ca^{2+} level.
- **PTH** secretion operates via a negative feedback system.
- If some stimulus causes the blood Ca^{2+} level to decrease, PT gland cells (**receptors**) detect this change and increase their production of a molecule **cyclic adenosine monophosphate** (cyclic AMP).

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Bone's Role in Calcium Homeostasis:

- The gene for PTH within the nucleus of a parathyroid gland cell (**the control center**) detects the intracellular increase in cyclic AMP (**the input**).
- As a result, PTH synthesis speeds up, and more PTH (**the output**) is released into the blood.
- The presence of higher levels of PTH increases the number and activity of osteoclasts (**effectors**), which **step up the pace of bone resorption**.
- The resulting release of Ca^{2+} from bone into blood returns the blood Ca^{2+} level to normal.

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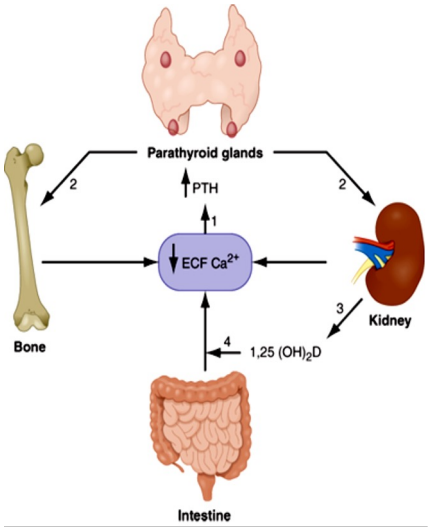
Bone's Role in Calcium Homeostasis:

- PTH also acts on the kidneys (**effectors**) to decrease loss of Ca^{2+} in the urine, so more is retained in the blood.
- PTH stimulates formation of **Calcitriol** **(active form of vit. D), a hormone that promotes absorption of Ca from foods in the gastrointestinal tract into the blood.**
- Both of these actions also help elevate blood Ca^{2+} level.



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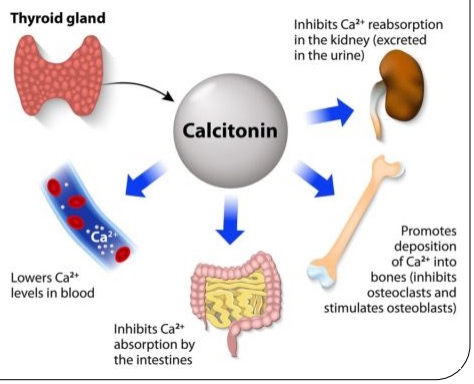
Bone's Role in Calcium Homeostasis:

- Another hormone works to decrease blood Ca^{2+} level. When blood Ca^{2+} rises above normal, parafollicular cells in the thyroid gland secrete **Calcitonin** (CT).
- CT inhibits activity of **osteoclasts**, speeds blood Ca^{2+} uptake by bone, and accelerates Ca^{2+} deposition into bones.
- The net result is that CT **promotes bone formation and decreases blood Ca^{2+} level**.



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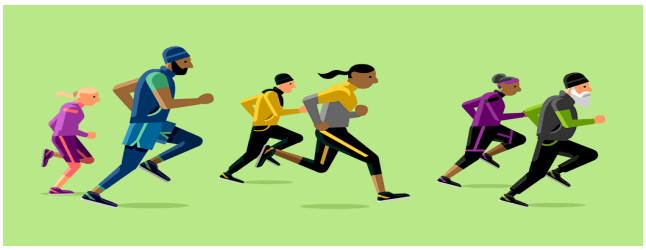
Exercise and Bone Tissue:

- Within limits, **bone tissue** has the ability to alter its strength in response to changes in mechanical stress.
- When placed under stress, bone tissue becomes stronger through increased deposition of mineral salts and production of collagen fibers by osteoblasts.
- Without mechanical stress, bone does not remodel normally because bone resorption occurs more quickly than bone formation.



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Exercise and Bone Tissue:

- Research has shown that high-impact intermittent strains more strongly influence bone deposition as compared with lower-impact constant strains. Therefore, running and jumping stimulate bone remodeling more dramatically than walking.

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Exercise and Bone Tissue:

- The main mechanical stresses on bone are those that result from the pull of skeletal muscles and the pull of gravity.
- **If a person is bedridden or has a fractured bone** in a cast, the strength of the unstressed bones diminishes because of the loss of bone minerals and decreased numbers of collagen fibers.
- In contrast, the bones of **athletes**, which are repetitively and highly stressed, become notably thicker and stronger than of nonathletes. Weight-bearing activities, such as walking or moderate weight lifting, help build and retain bone mass.

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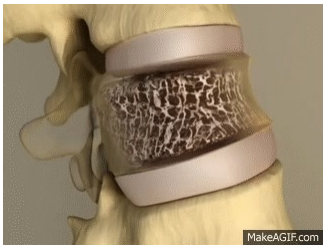
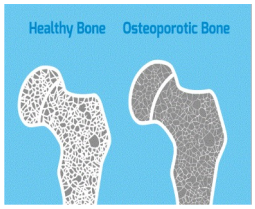
Aging and Bone Tissue:

- In old age, loss of bone through resorption occurs more rapidly than bone gain.
- Because women's bones generally are smaller and less massive than men's bones to begin with, loss of bone mass in old age typically has a greater adverse effect in females. These factors contribute to the higher incidence of osteoporosis in females.





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Aging and Bone Tissue:

- **There are two principal effects of aging on bone tissue:**

1. Loss of bone mass:

- Loss of bone mass results from demineralization, the loss of Ca and other minerals from bone extracellular matrix.

In Females: Loss of bone mass usually begins:

- after age 30,
- accelerates greatly around age 45,
- continues until ~30% of the Ca in bones is lost by age 70.
- Once bone loss begins in females, ~8% of bone mass is lost every 10 years.

In Males: Loss of bone mass:

- Ca loss typically does not begin until after age 60, and about 3% of bone mass is lost every 10 years.

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Aging and Bone Tissue:

2. Brittleness:

- Results from a decreased rate of protein synthesis.
- Recall that the organic part of bone extracellular matrix, mainly collagen fibers, gives bone its tensile strength. The **loss of tensile strength** causes the bones to **become very brittle and susceptible to fracture**.

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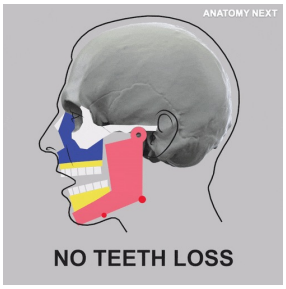
Aging and Bone Tissue:

- In some elderly people, collagen fiber synthesis slows, in part due to diminished production of growth hormone.
- In addition to **increasing the susceptibility to fractures**, loss of bone mass also leads to **deformity, pain, loss of height, and loss of teeth**.



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Questions and Comments:

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