1. **Epiphysis (Head):**
   - *Epi* = “above” ; *physis* = “growth”
   - Enlarged distal and proximal ENDS

   **Epiphysis Composition:**
   - **Spongy Bone:** Majority
   - **Compact Bone:** Thin covering

2. **Diaphysis: Dia** = “through”
   - Narrow, central long portion = *shaft*
   - **Shaft Composition:** Hollow
★ Compact bone tube
  ✓ Central space: Marrow (Medullary) Cavity
  ✓ Contents: Yellow Marrow
    ⇒ Areolar & Adipose tissue

★ Function: Support blood vessel & energy storage

3. Metaphysis: “Union”
  - Location: Between Epiphysis & Diaphysis
  - Site of bone growth: GROWTH PLATE
    ✓ Epiphyseal Plate
**Growth plate Composition:**

- **Juvenile:** Hyaline Cartilage
  - Active Bone Growth (lengthening)
  - Hyaline cartilage: Epiphyseal Plate

- **Adult:** Bone
  - Ossifies into the Epiphyseal Line
  - Non-growing adult bone
Bone Formation:
- Carefully regulated by **Hormones**
  - Begins: ~ 6–8 weeks after fertilization
  - Ends: ~ 25 years of age
- Results from replacing connective tissue with bone: **Ossification**
  1. Fibrous Connective Tissue
  2. Cartilage

**2 Forms of Ossification:**

**Stages of Endochondral Ossification**

1. Intramembranous (IM) Ossification
   - Intramembranous (between membranes)
     - Ossification occurs in flat bones
       - Skull, mandible, clavicle
       - Fibrous membrane, Os. center, trabeculae
• Location: Embryonic or Fibrous CT
  a. **Mesenchymal cells**: Differentiate into Osteoblasts

  ![Mesenchymal Cells](image1)

  - An ossification center appears in the fibrous connective tissue membrane.
  - Selected centrally located mesenchymal cells cluster and differentiate into osteoblasts, forming an ossification center.

b. **Osteoblasts** secrete **Osteoid Matrix**
   - **Site**: Ossification Center
   - **Form**: Lacunae
   - **Mature**: into **Osteocytes**

  ![Osteoblasts and Osteoid Matrix](image2)

  - Bone matrix (osteoid) is secreted within the fibrous membrane.
  - Osteoblasts begin to secrete osteoid, which is mineralized within a few days.
  - Trapped osteoblasts become osteocytes.

c. Bone growth is **Non-uniform**
   - **Projections of matrix**: Spicules
   - Spicules unite to form: Trabeculae

da. Resulting structure: **Spongy Bone**

  ![Spongy Bone](image3)
• 3 primary STIMULI:
  a. Fetal Hormones
  b. Chronic Mechanical Stress
  c. Connective Tissue Injury

• Sites of Intramembranous ossification
  * Skeleton: Skull, Mandible, Clavicles, Patella

* Stress: Dermal Bones develop in CT
  ➢ Bone Spurs
**Injury:** Contusion, damaged fibers

✔ **Clinical Importance:** Myositis Ossificans

---

2. **Endochondral Ossification:**

   ‣ endo = “within”; Chondral = “cartilage”

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- **Location:** Within **Hyaline Cartilage**
  - Cartilage provides framework: "organized ossification"
  - Result: Long Bone Formation
    "Shaft – Diaphysis"
• Steps of Endochondral Ossification:

a. Cartilage framework formed

b. Cartilage plate grows (Hypertrophy):
   * Centrally located Chondrocytes DIE
   ≈ Cause: Lack of nutrients (Avascular)
c. **Perichondrium** Mesenchymal cells differentiate into osteoblasts
   ⇒ Result: **Periosteal Bone collar**

d. **Chondrocyte death**: Allow **blood vessels** to invade cartilage

e. **Osteoblasts**: Migrate in with vessels into cartilage center (from **periosteum**)

f. **Osteoblasts**: Secrete **osteoid matrix** in center:
   * **Primary Ossification Center**
f. Remodeling occurs

- **Osteoclasts:** Degrade bony center
  - Result: Marrow / Medullary Cavity

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9. Epiphysis enlarges:

- Central Chondrocytes die
- Periosteal osteoblasts migrate into epiphysis
- Convert epiphysis into bone:

<table>
<thead>
<tr>
<th>Articular (epiphyseal) cartilage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proliferating cartilage</td>
</tr>
<tr>
<td>Maturing cartilage</td>
</tr>
<tr>
<td>Hyper trophy and provisional calcification</td>
</tr>
<tr>
<td>Primary spongyosa</td>
</tr>
<tr>
<td>Bone collar</td>
</tr>
<tr>
<td>Bone marrow</td>
</tr>
<tr>
<td>Osteogenic periosteum</td>
</tr>
</tbody>
</table>

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h. Epiphyseal Cartilage: Separates epiphysis and diaphysis
  - Epiphyseal plate
  - Location: Metaphysis
  - Significance: Site of bone elongation
1. **Epiphyseal Plate:**
   a. Epiphyseal side – Growing
   - Chondrocytes: *Interstitial Growth*
     
     "*Increase size from within*
     
     "*Zone of Proliferation*"

   Interstitial growth
   "Stacks of Chondrocytes"
b. Diaphyseal side - Dying
- **Chondrocyte** death

*Zone of Hypertrophy*
Ossified by osteoblasts

- Zone of Hypertrophy: Chondrocytes dying
- Zone of Calcification: Bone Forming

2. Bone Lengthening:
a. **Growth:**
- **Chondrocyte** activity **equals osteoblast** activity

- Length of bone increases.
- Thickness of epiphyseal plate remains unchanged.
- Bone is added to diaphysis.

- New cartilage is formed.
- New diaphysis is formed.
- Zone of calcification - zone of hypertrophy.
b. Cessation of Bone elongation: PUBERTY

- Osteoblast activity slightly faster than Chondrocyte activity
- Orchestrated by Sex Hormones

Puberty: Sex hormones stimulate BOTH Osteoblast & Chondrocytes activity

Result: Growth “spurt”

End Result: Complete ossification of Epiphyseal Plate into Epiphyseal Line
Hormones: Mostly used to maintain blood calcium homeostasis & growth rate.

Mechanical stress and gravity: bone remodels to allow it to withstand stresses.

Control of Remodeling

Bone Repair

Remnant: Epiphyseal Line

Bone formation stages:
1. Hematoma formation
2. Fibrocartilage matrix formation
3. Bone callus formation
4. Bone remodeling
Bone Aging:

- **Older Adult**: Osteoblast activity slows
- **Osteopenia**: Skeleton gradually weakens
- **Osteoporosis**: Weakening compromising skeletal function

Bone Growth Disorders:

**Achondroplastic Dwarf**