The processes of osteogenesis in fracture healing: In this region of a recent fracture, callus is seen forming at the broken ends of bony trabeculae that extend to the center from the left and top.

The steps of fracture healing may be summarized as follows:

**Phase I**
1. Bleeding and fracture hematoma forms
2. Inflammation
3. Next 2-3 Days, granulation tissue formation
4. Osteogenic cells invade tissue and lay down osteoid

**Phase II**
5. At 3 weeks a soft callus of osteoid and cartilage forms
6. Hard tissue callus forms in 6 - 12 weeks
7. Clinical union of bone ends occurs in 12 - 16 weeks

**Phase III**
8. Remodeling of united fracture
The four biomechanical stages of fracture repair

White et al. (1977)

Stage 1: Bone fails through original fracture site; has low stiffness similar to soft tissue stiffness. Fracture site has low stiffness and low strength.

Stage 2: Bone fails through original fracture site, but stiffness is more similar to mineralized tissue. Fracture site has normal bone stiffness but low strength.

Stage 3: Bone fails partially through original site and partially through surrounding bone. Fracture site has normal bone stiffness and medium strength.

Stage 4: Site of failure is not related to original fracture. Fracture site has normal bone stiffness and normal bone strength.

Perren's theory of interfragmentary strains

- $\varepsilon = 0$ $<$ 5%: Bone Formation
- $\varepsilon = 5$ $<$ 10% and $>$ 2%: Marrowage Formation
- $\varepsilon = 0$ $<$ 10% and $>$ 10%: Osmotic Tense Formation
The theory of Carter and Blenman (1987, J. Biomechanics) for relating mechanical stimulus to fracture healing.

Carter and Blenman's theory in case of poor blood supply to the fracture site.

Carter, Blenman et al's theory applied to fracture healing in a long bone subjected to one axial load and two bending moments (1987, J. Biomechanics).
An example of how fracture fixation devices may relate to mechanically mediated fracture healing theories.

Common external fixators used for repairing tibial fractures

Radiographic images of external fixation of the radius
The means by which fixator geometric factors affect fixator stiffness is listed below:

1. Increased pin diameter increases fixator rigidity
2. Increased pin number increases fixator rigidity
3. Decreased side bar separation increases fixator rigidity
4. Decreased pin separation increases fixation rigidity

Examples for plate fixators

Examples for intramedullary rod fixations
Ender nails bridging a femoral shaft fracture and an intertrochanteric fracture.

Rush rod bridging a distal fibular fracture.

In a general comparison of external fixation, intramedullary rod fixation, and internal plate fixation in dog tibia tested under bending, axial distraction and torsion, plate fixation was seen to consistently give the highest rigidity. Intramedullary rods and external fixators with half a frame were consistently low, while external fixation with full pins was close to plate fixation for bending and torsion.

When plate and rod fixators were tested for femoral shaft fixation, plates and interlocking intramedullary rods provided similar bending stiffness.