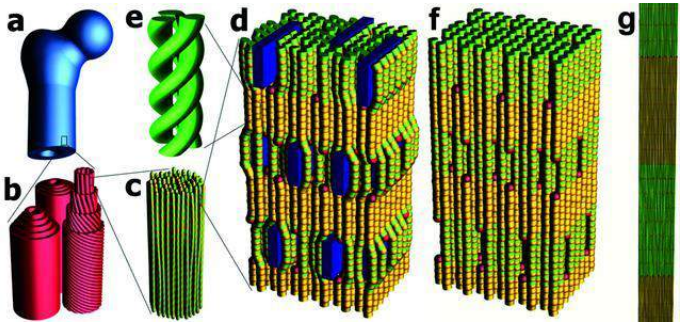
Bone healing, delayed fracture healing and nonunion

Norbert Wiegand

2/3 of traumatology: treatment of fractures

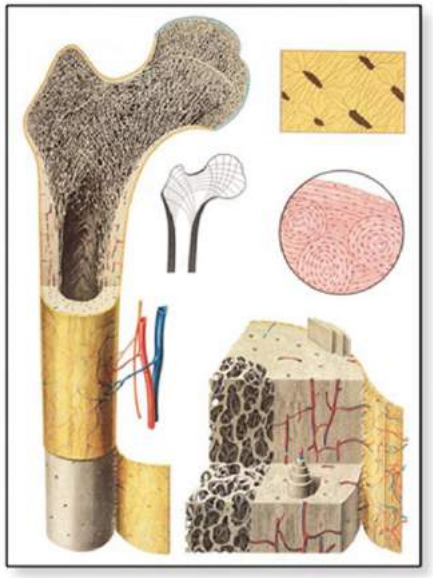
- We have to understand:
  - Structure of the bone
  - Biology of the bone
  - Bone healing

Types of Bone



- Lamellar Bone
  - Collagen fibers arranged in parallel layers
  - Normal adult bone
- Woven Bone (non-lamellar)
  - Randomly oriented collagen fibers
  - In adults, seen at sites of fracture healing, tendon or ligament attachment and in pathological conditions

Bone Composition

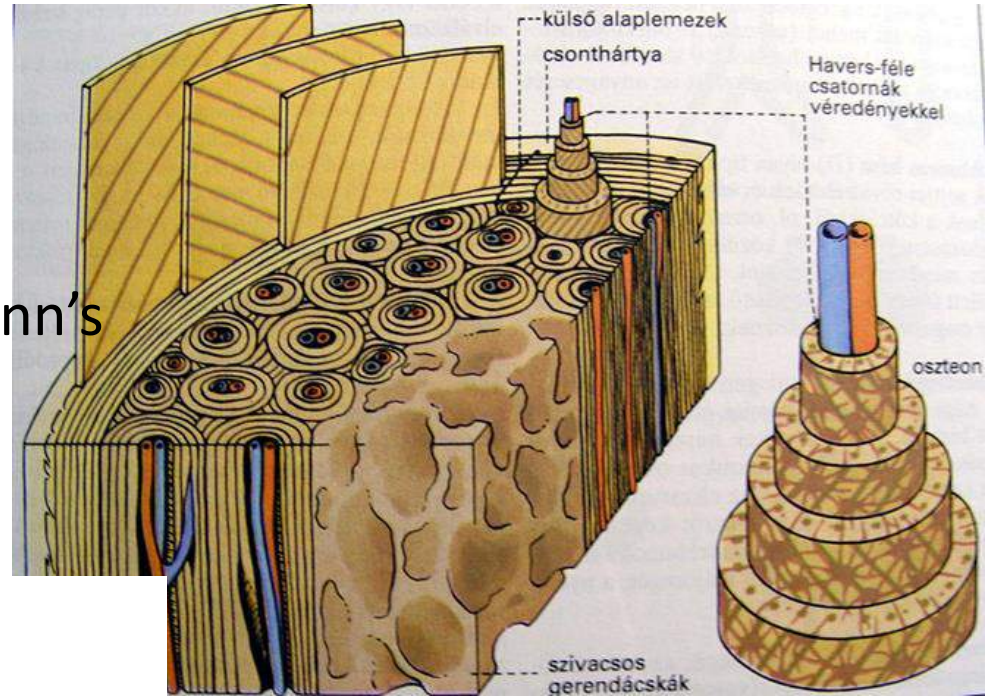


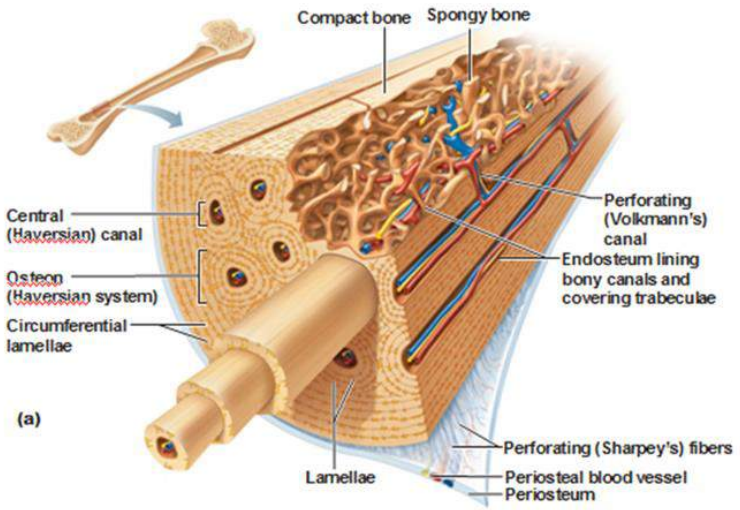
- Cells
  - Osteocytes
  - Osteoblasts
  - Osteoclasts
- Extracellular Matrix
  - Organic (35%)
    - Collagen (type I) 90%
    - Osteocalcin, osteonectin, proteoglycans, glycosaminoglycans, lipids (ground substance)
  - Inorganic (65%)
    - Primarily hydroxyapatite $Ca_5(PO_4)_3(OH)_2$

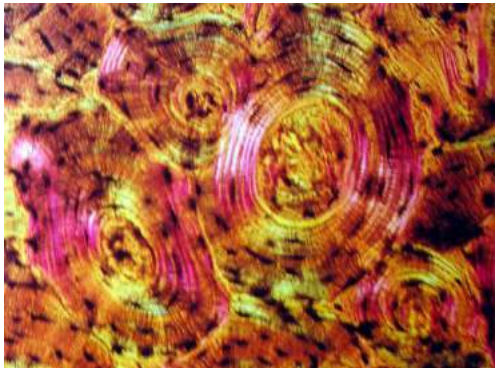
Normal lamellar bone

Comprised of osteons (Haversian systems)

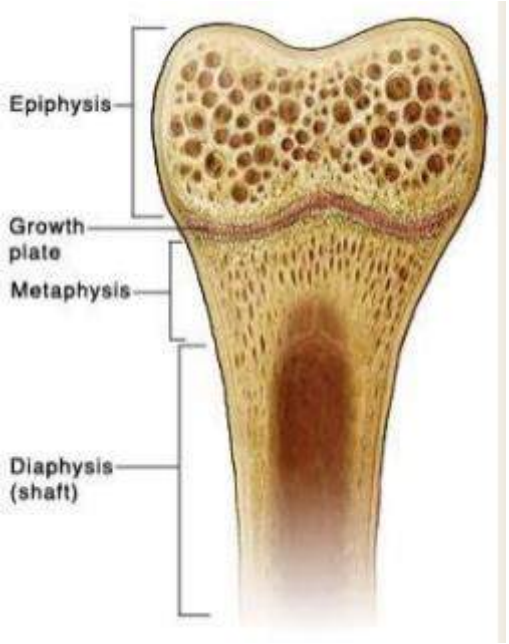
Osteons communicate with medullary cavity by Volkmann's canals

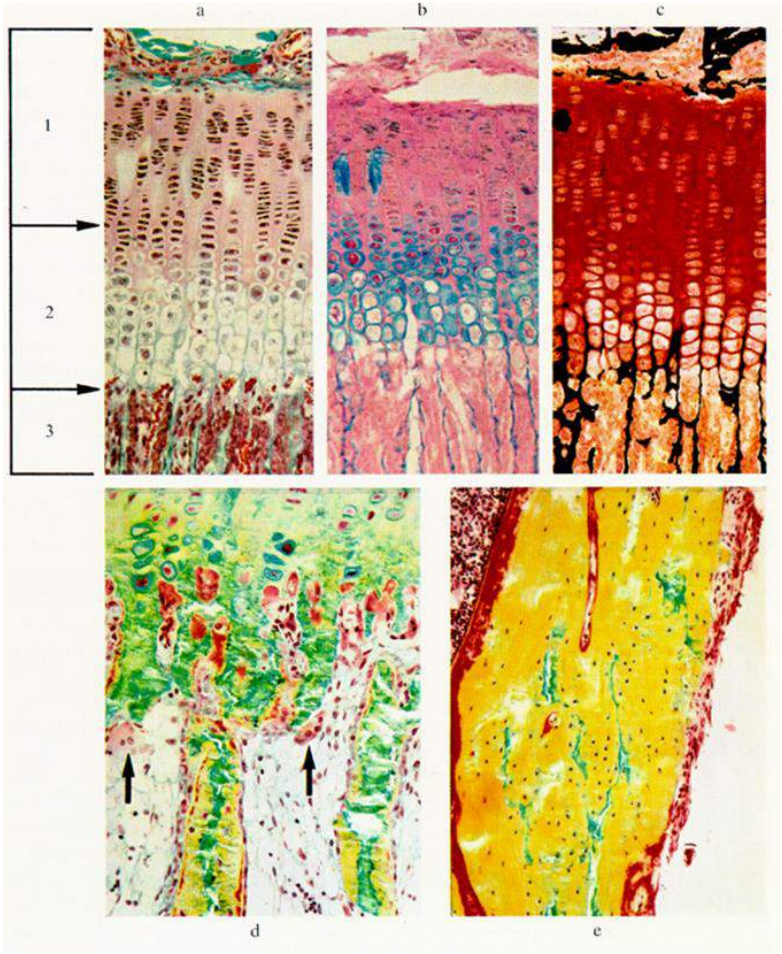






Longitudinal growth of the bone by epiphyseal plate





Definition of bone fracture

- A *bone fracture* is a medical condition in which there is a damage in the continuity of the *bone*.
- A *bone fracture* may be the result of high force impact or stress, or a minimal trauma *injury* as a result of certain medical conditions that weaken the *bones*, such as osteoporosis, *bone* cancer, ...

A fractured bone results in ...

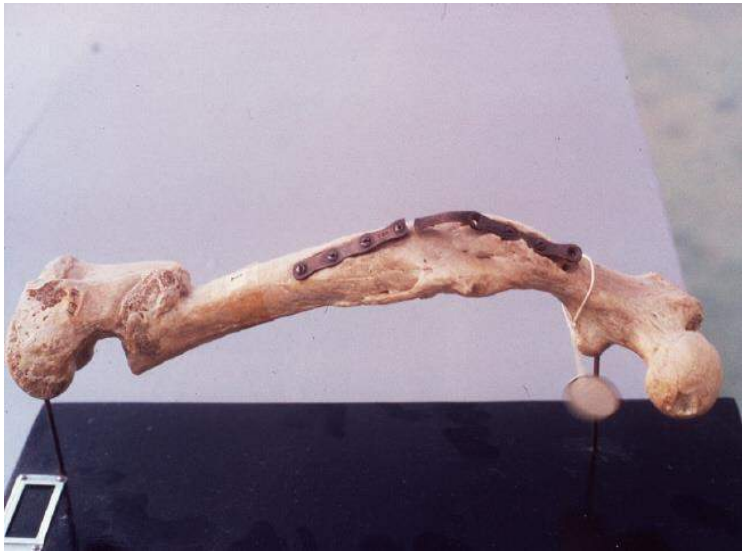
Interruption of

Circulation

Force transmission

Fracture healing

A broken bone heals because...



...it is broken!

Dr.Alan Apley

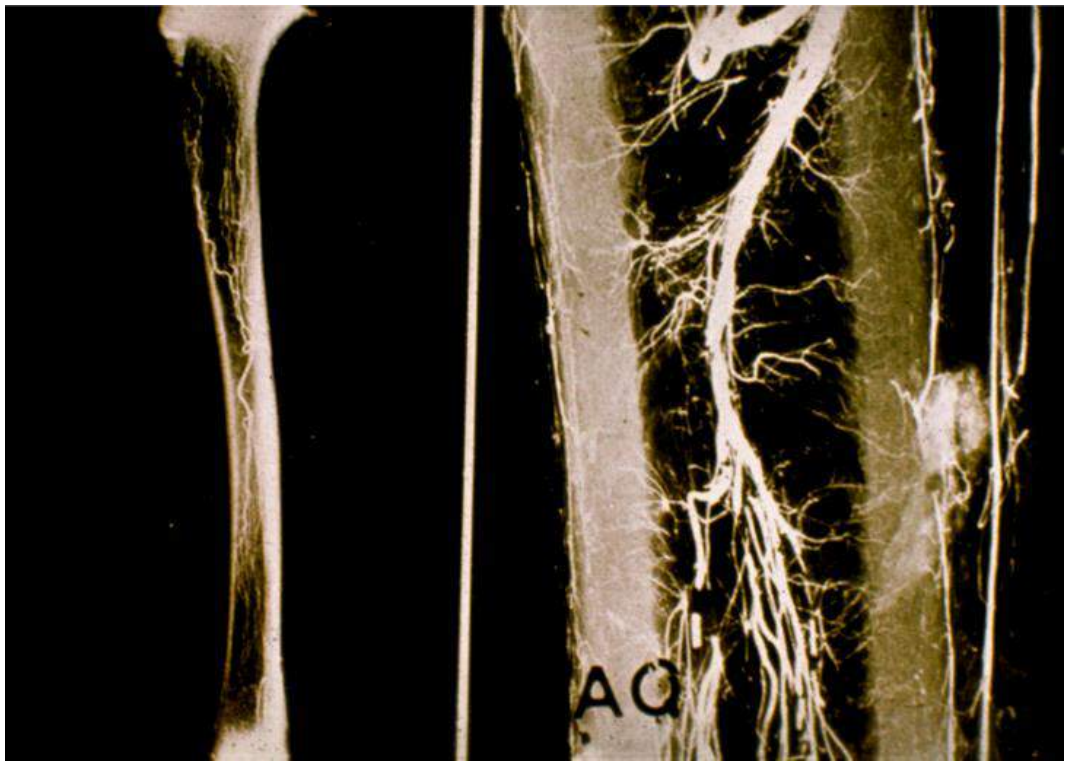
However it needs a favorable biological and mechanical environment!!!

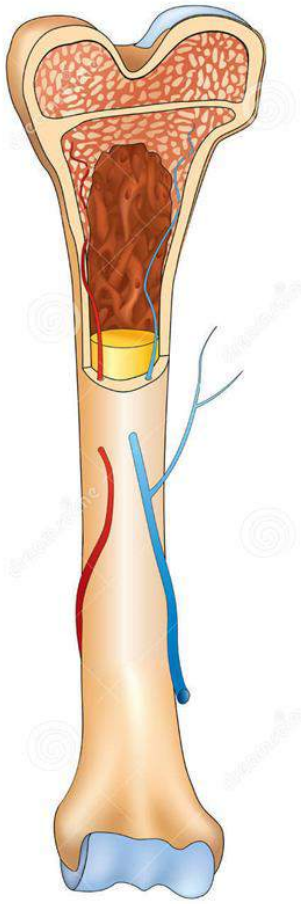
Blood supply of the bone:

periostealis

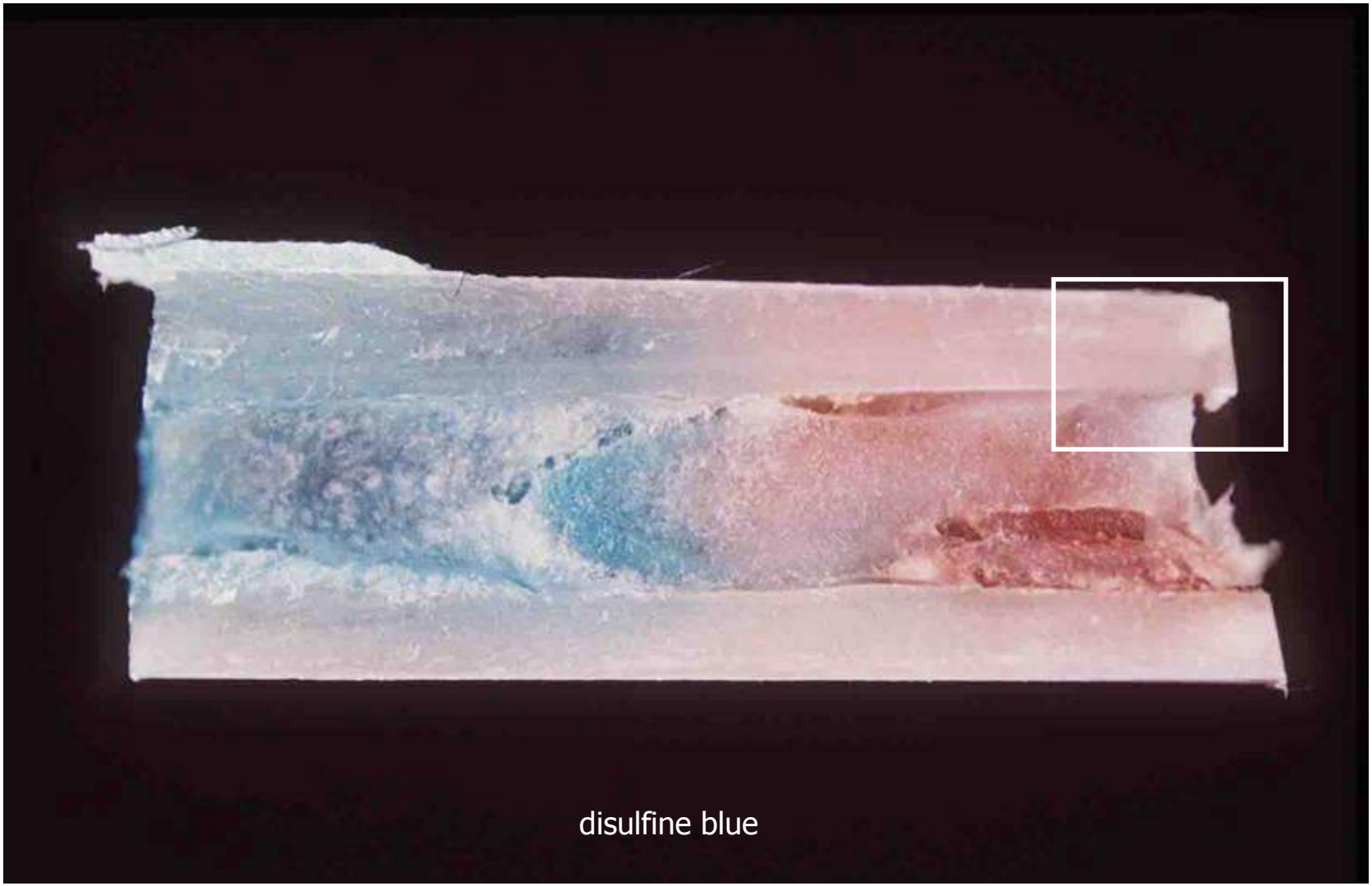
intramedullar: nutrient artery

metaphyseal



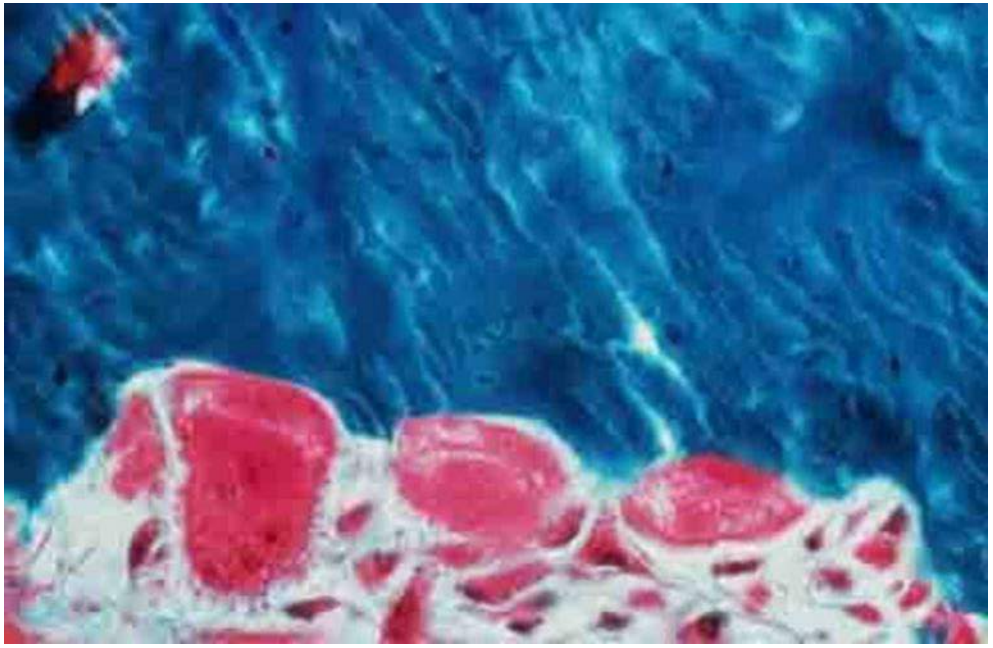


Injured blood supply



Basic requirements of bone healing is adequate biological activity:

- 1. living pluripotent cells
- 2. blood supply

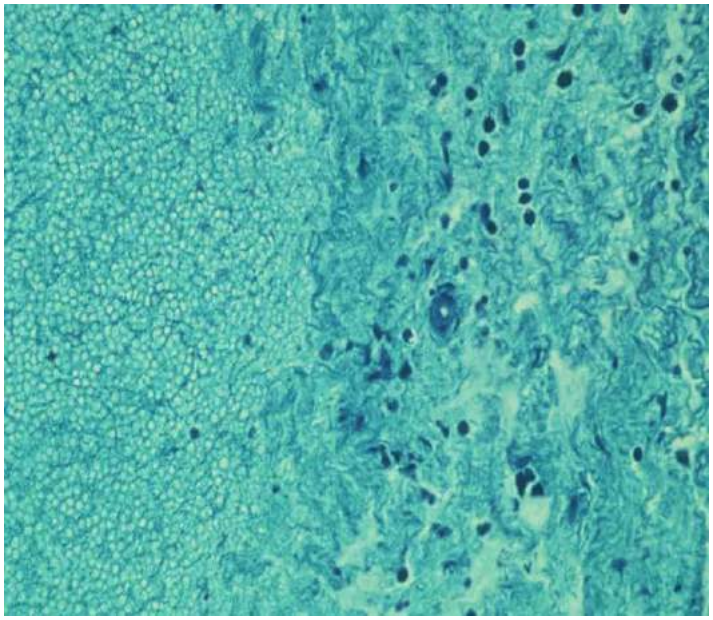


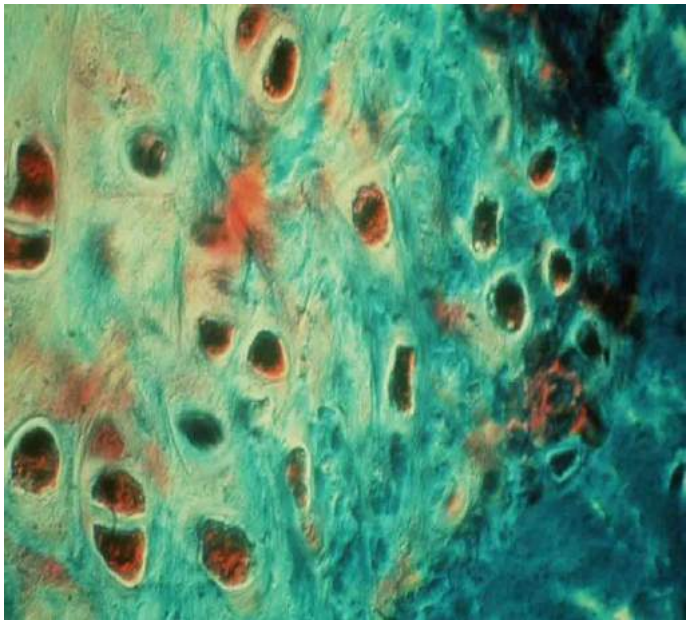
Stages of Fracture Healing

- Inflammation
- Repair
- Remodeling

Cascade of tissue differentiation following a fracture

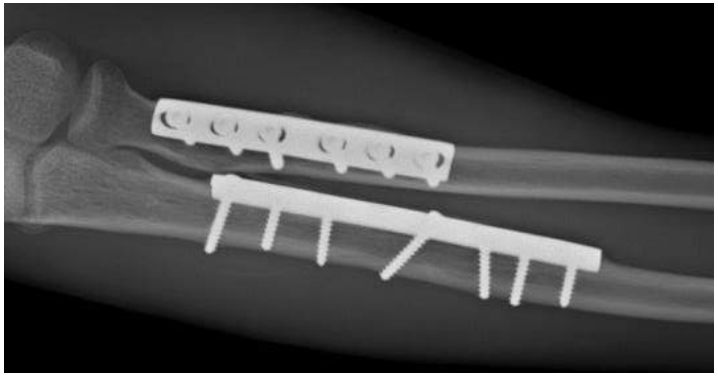
- Hematoma
- Granulation tissue
- Connective tissue
- Fibrocartilage
- Mineralized cartilage > bone



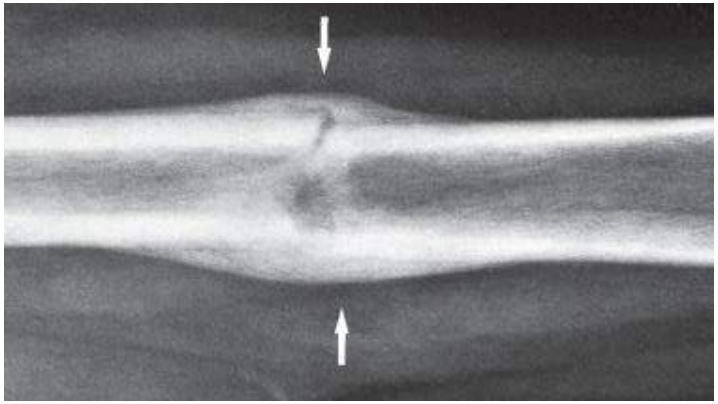


Different types of bone healing

Primary, angiogenic or contact bone healing

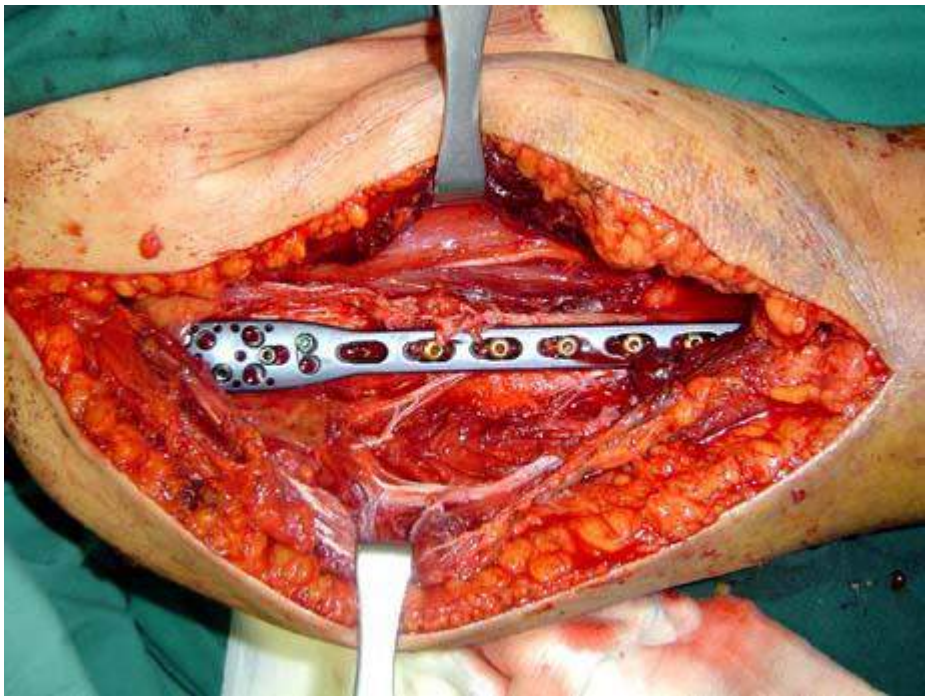


Secondary bone healing

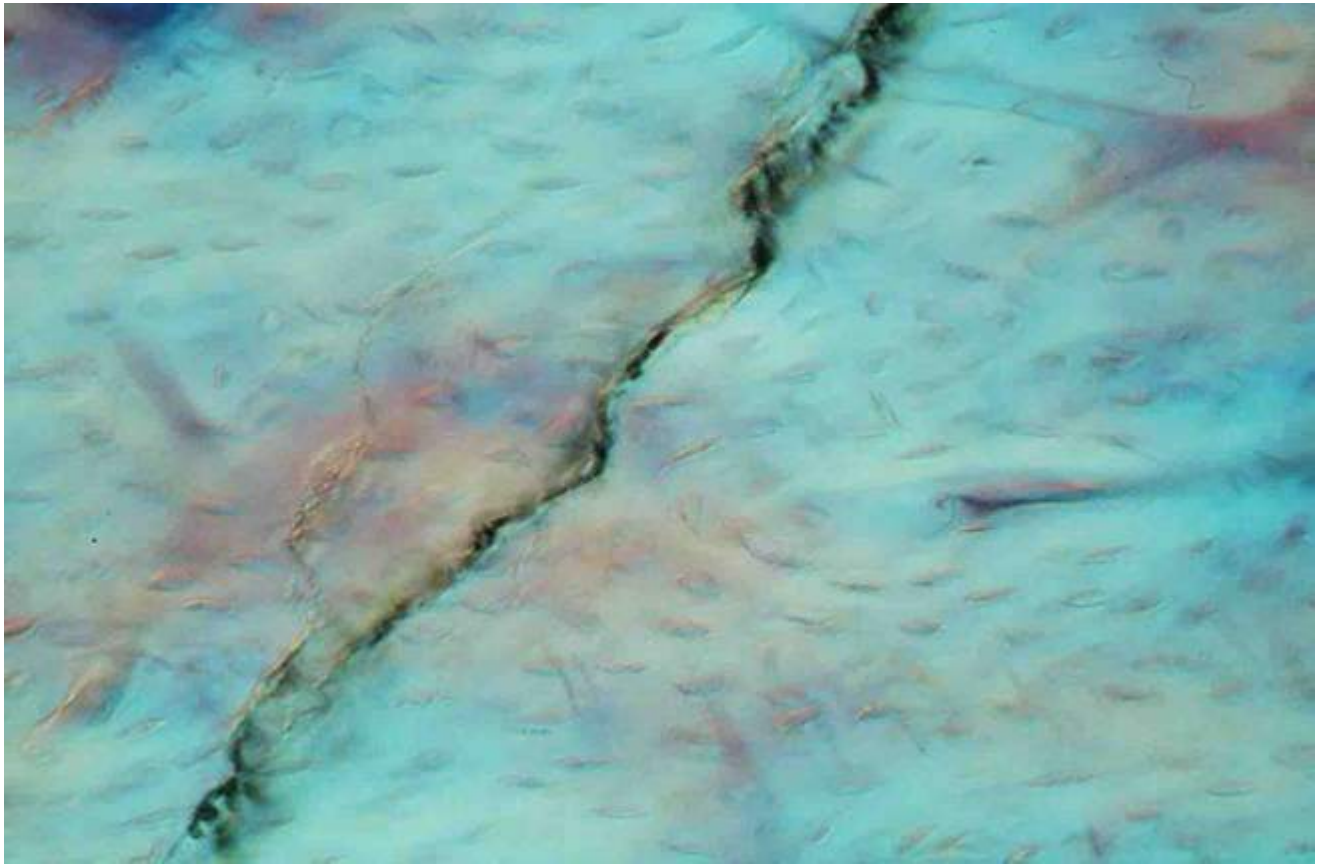


Primary, angiogenic or contact bone healing

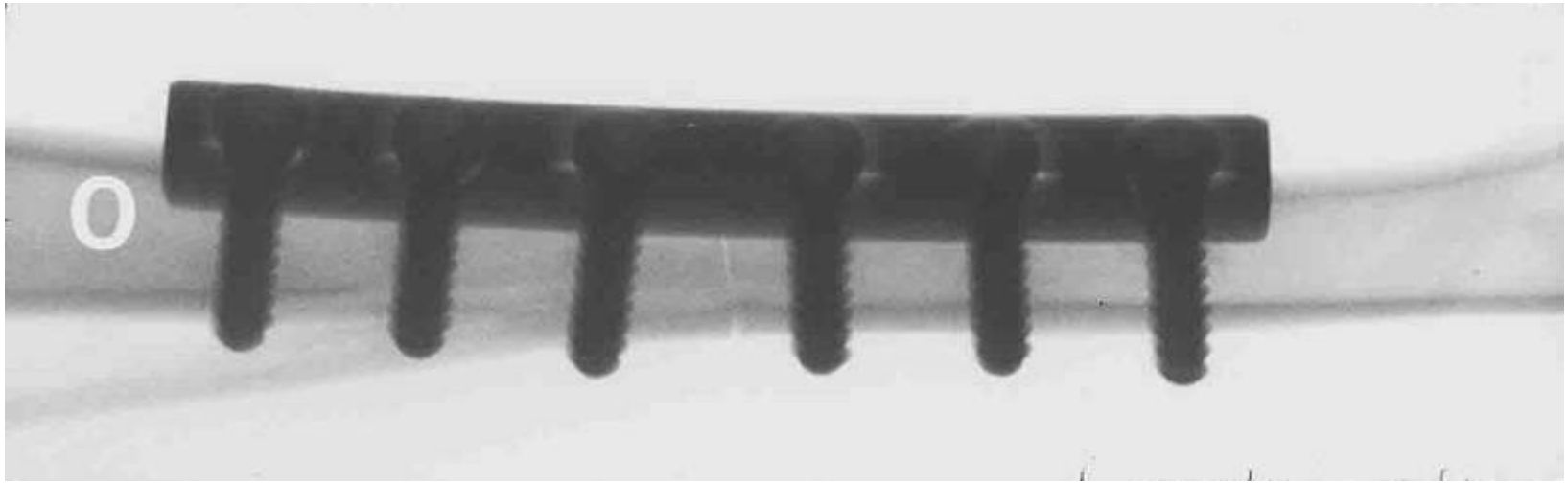
- Absolut stability
- Anatomical reposition
- No callus formation
- Not a natural way!



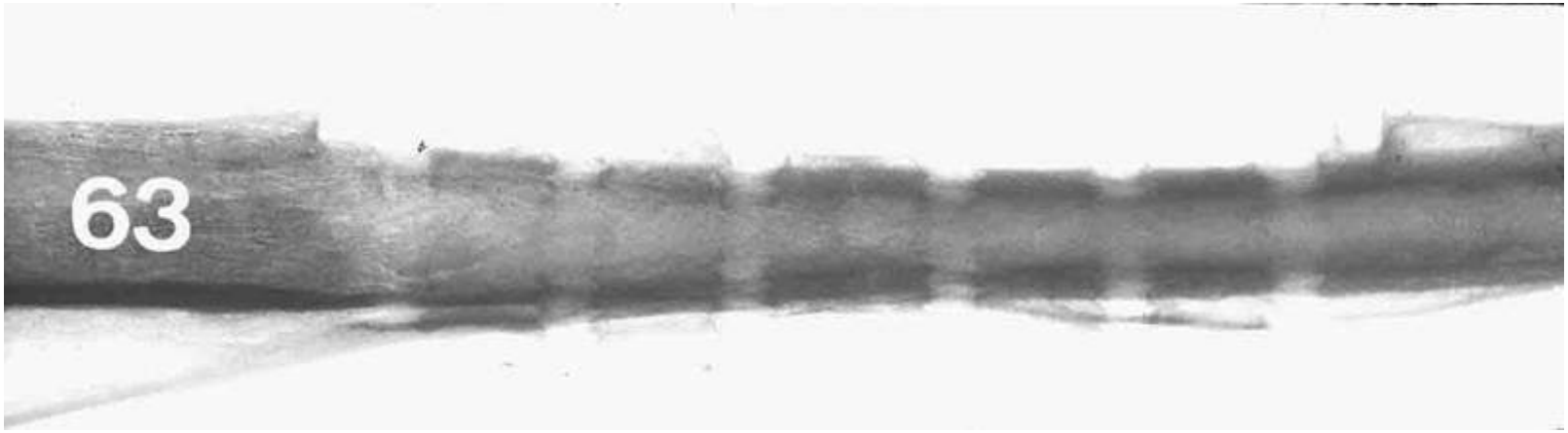
Anatomical, perfect adaptation



And absolute stability

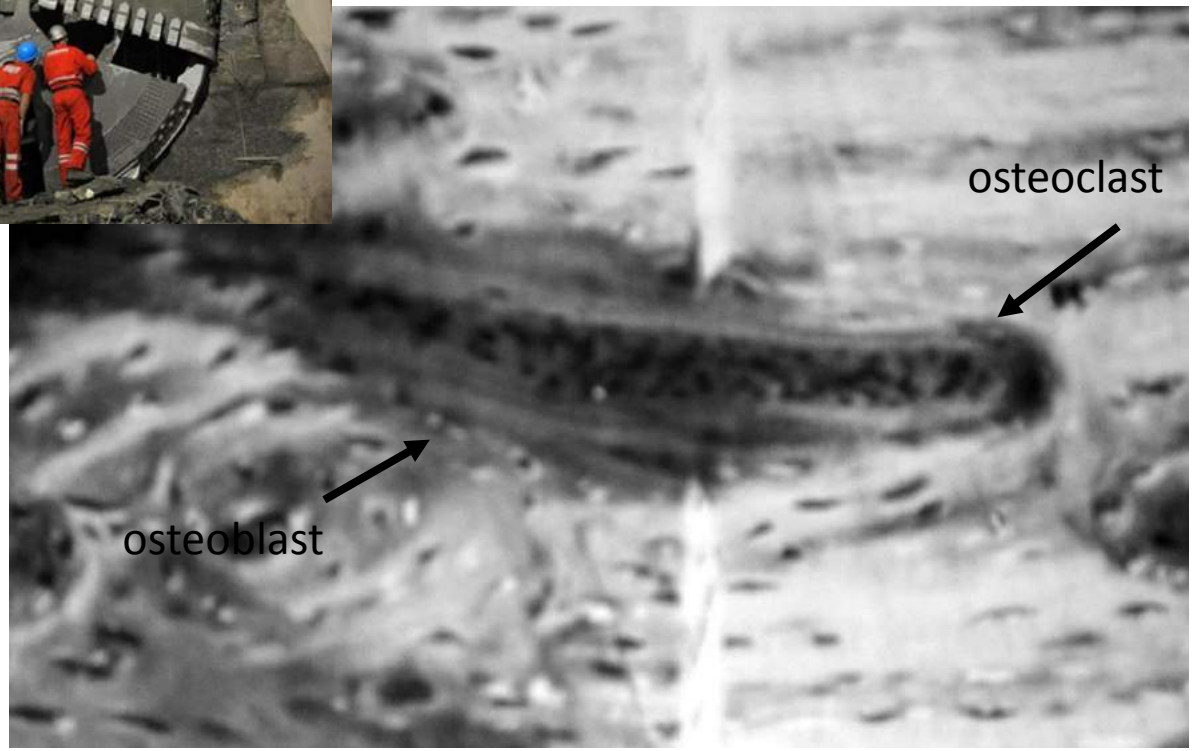


Leads to primary bone healing

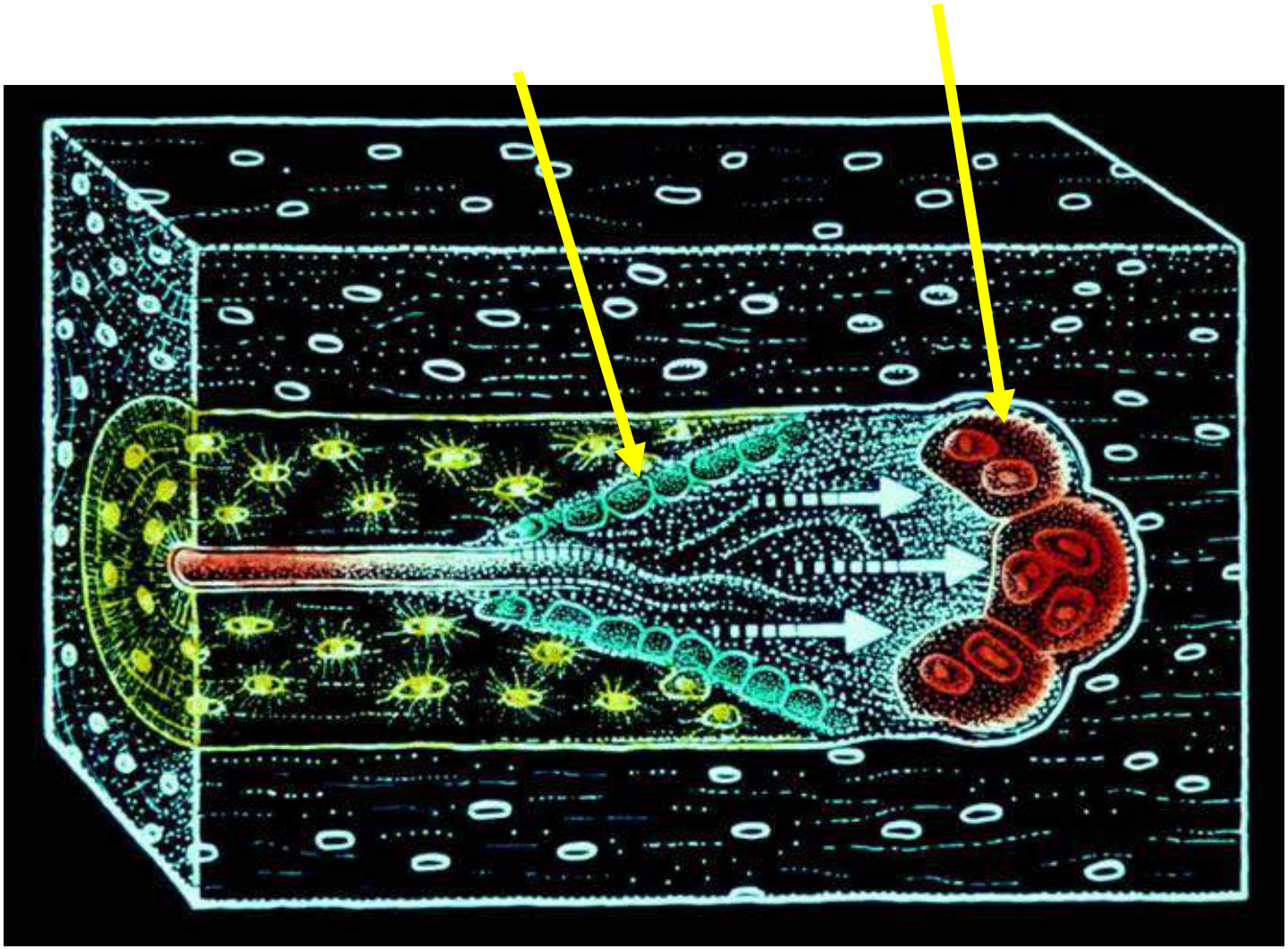


Remodeling of the Haversian system:

„cutter head (shield)” with the osteoclasts tear down the old bone and osteoblasts produce a new vascularized osteon.

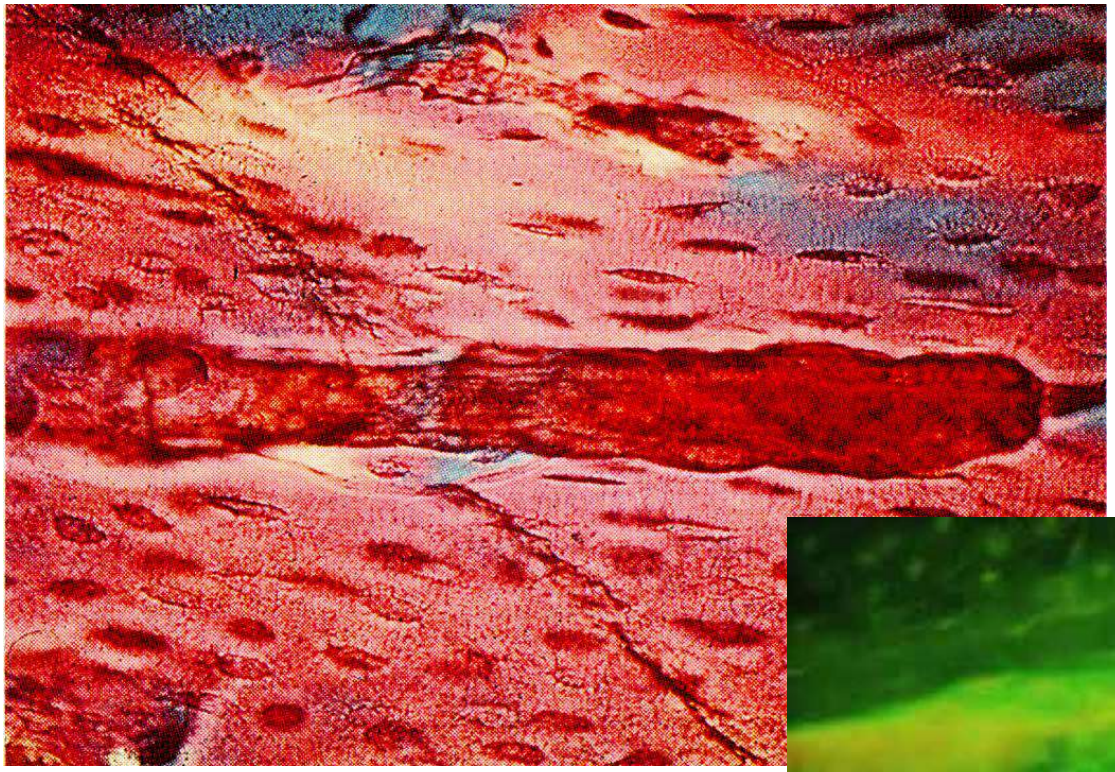


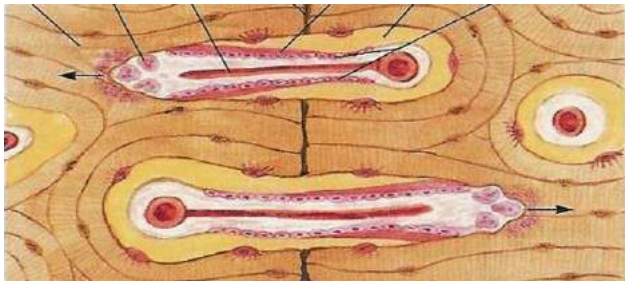
Osteon: the cutter head at the right tip with osteoclasts and the conical surface with osteoblasts

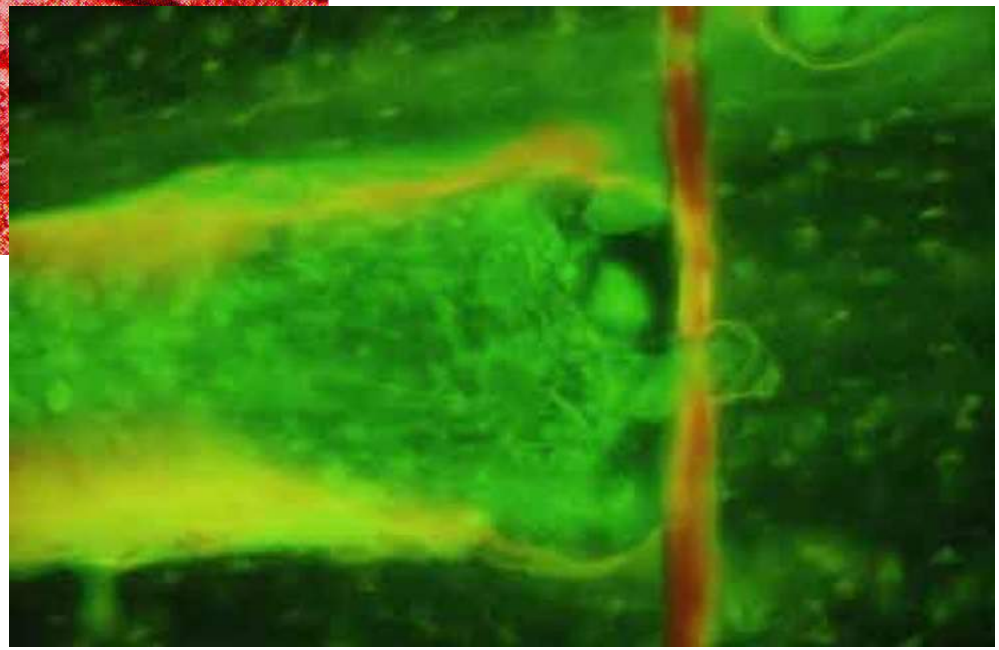


Primary bone healing

Cutting cone mechanism



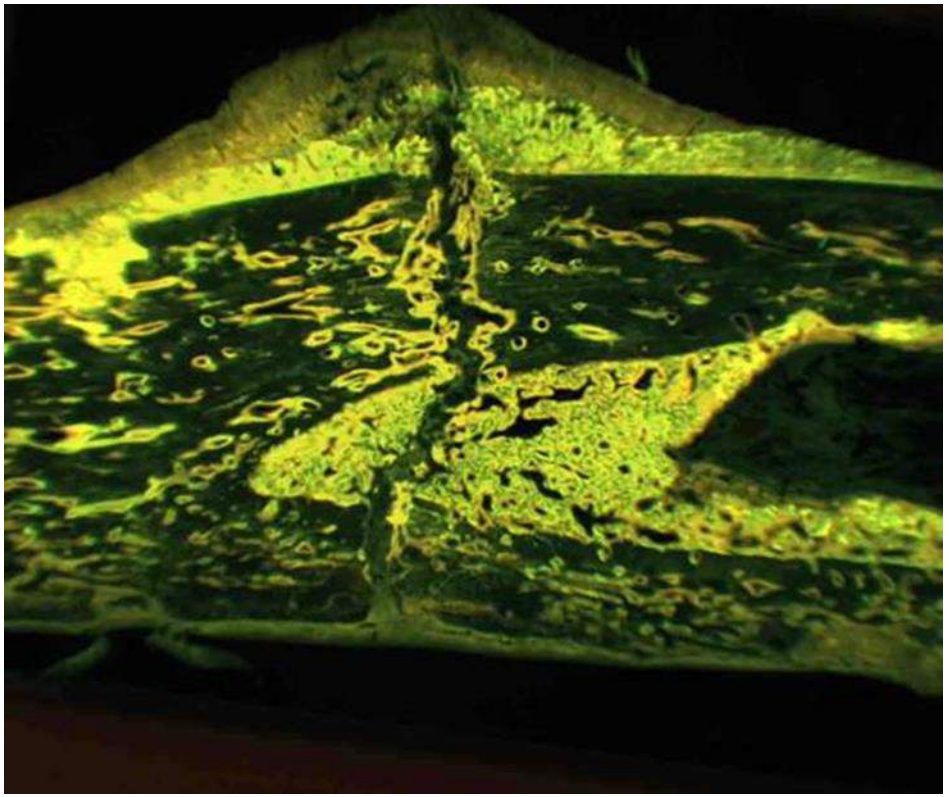




Primary bone healing of a forearm fracture

Secondary bone healing

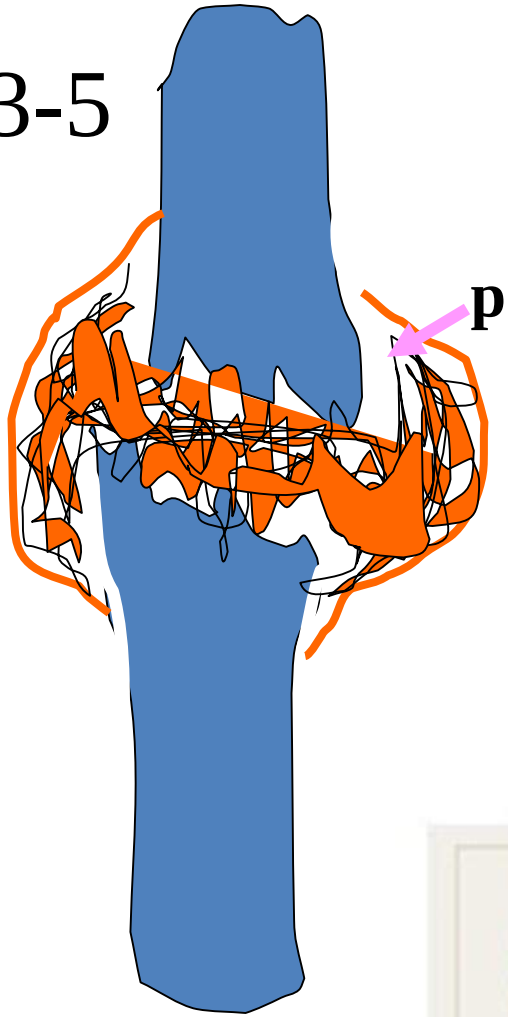
- Relative stability
- Reposition
- Callus formation
- Natural way

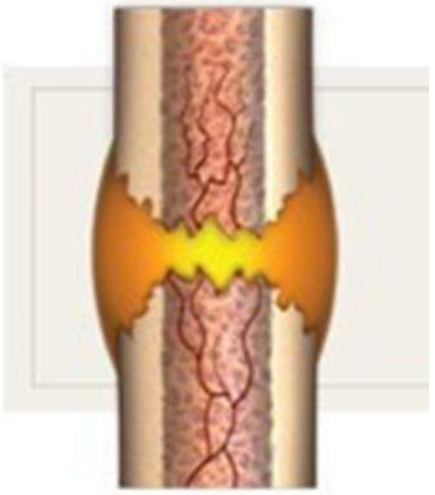


Secunder healing

1. Inflammation phase 3-5

Macrophages and leukocytes move into the haematoma to scavange debris and product pro-inflammatory agents. Granulation tissue forms, this is the callus precursor.

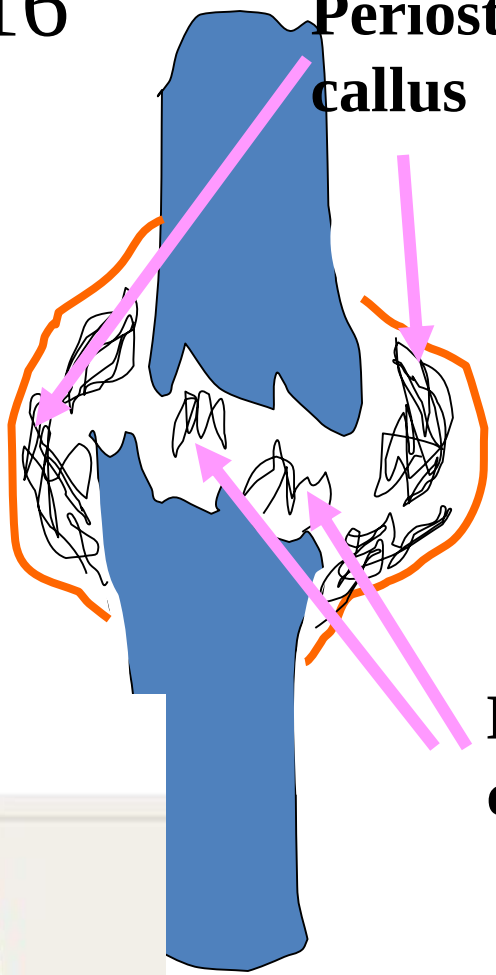


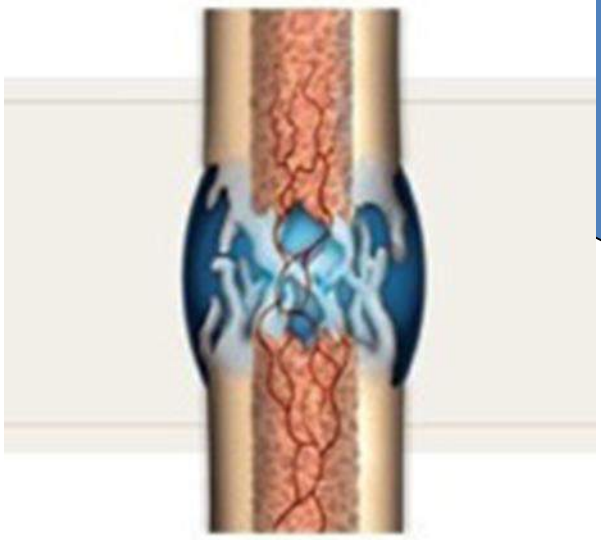


2. Reparation phase:5-16

Soft callus

Growth of new blood vessels. Fibroblasts, chondrocytes produce collagen fibers and this collagenous callus results a fixation of the bone fragments.

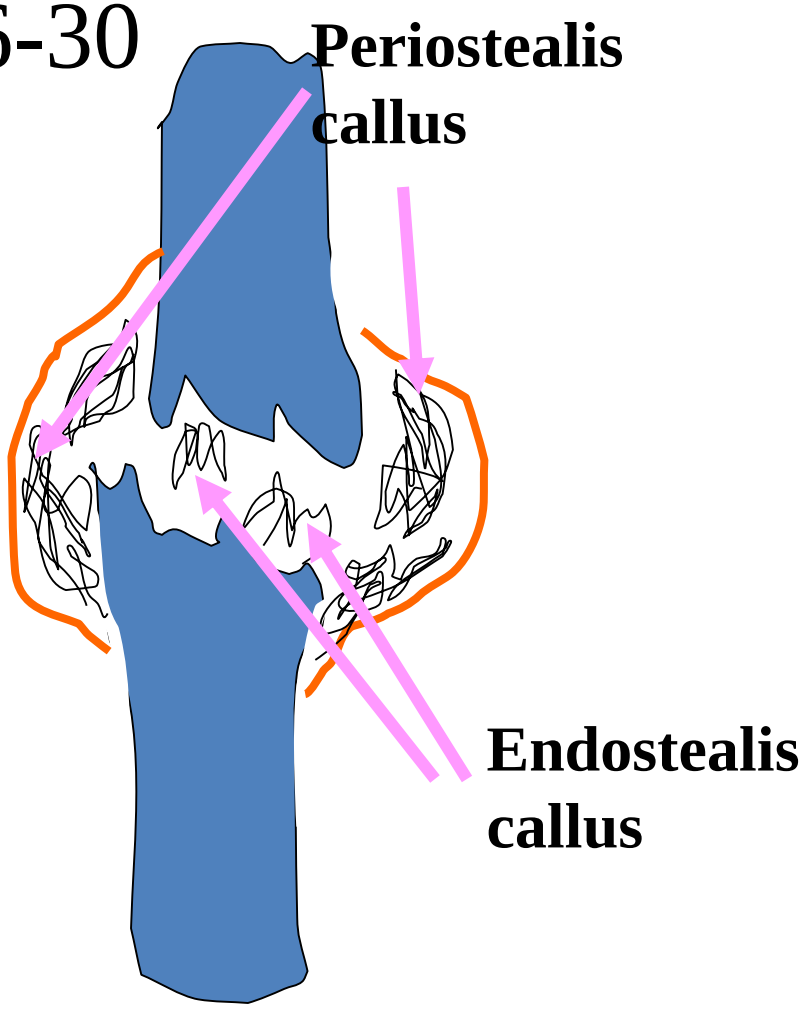


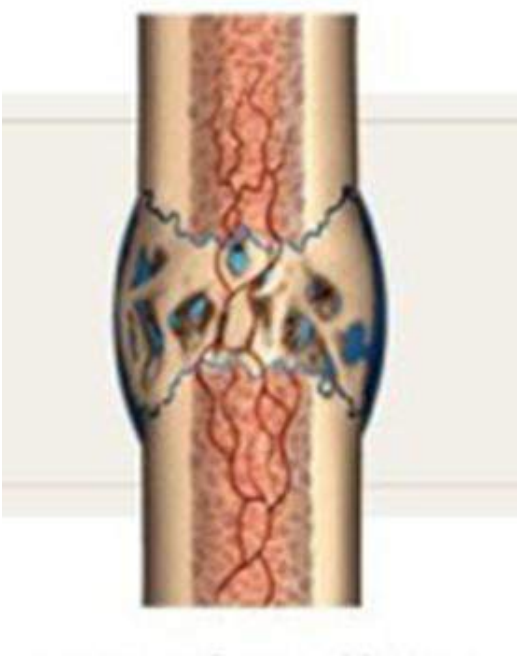


2. Reparation phase: 16-30

Hard callus

Through enchondral ossification and direct bone formation woven bone replaces the soft callus.



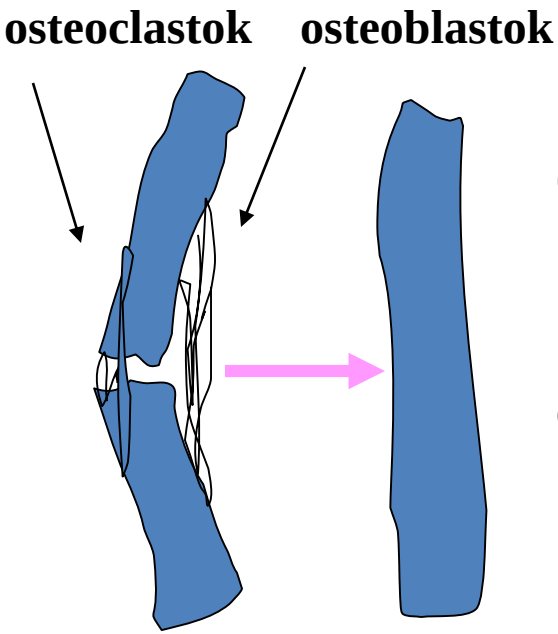


18-year-old m, motocycle accident, bilat. femur fractures, IM (intramedullary) nailing as emergency procedure. UFN (unreamed femoral nail) as splint providing relative stability.

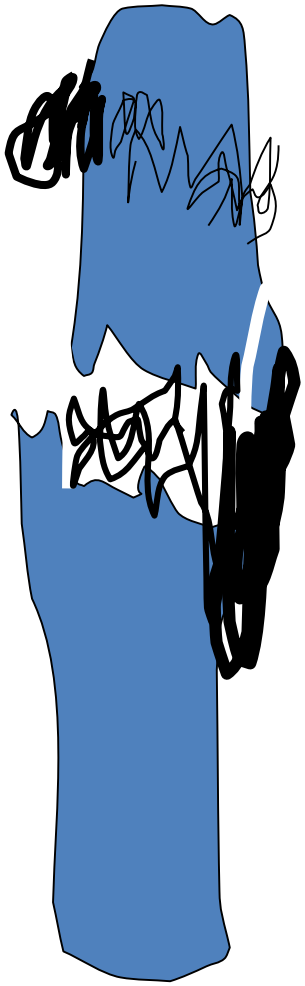
3. Remodeling phase

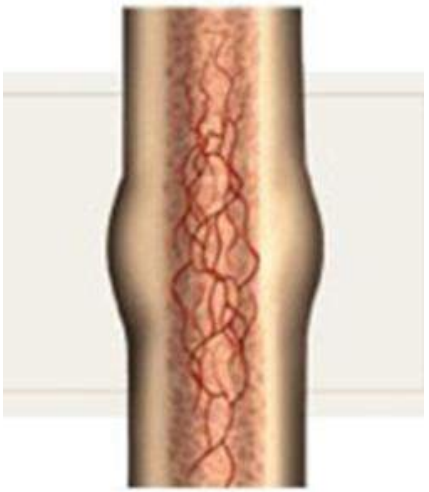
Highly organized cortical bone replaces the weaker woven bone

Bone is the only tissue to heal without scar

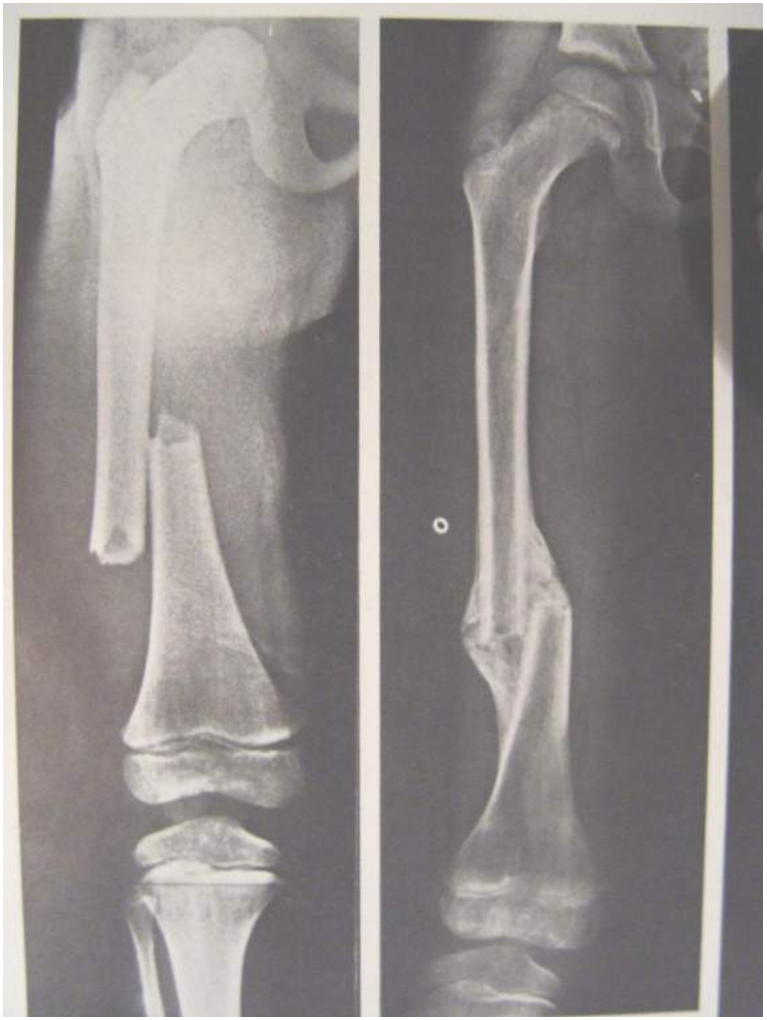


Osteblasts produce a new bone at the site of load and ostoclast remove the bone at opposite site



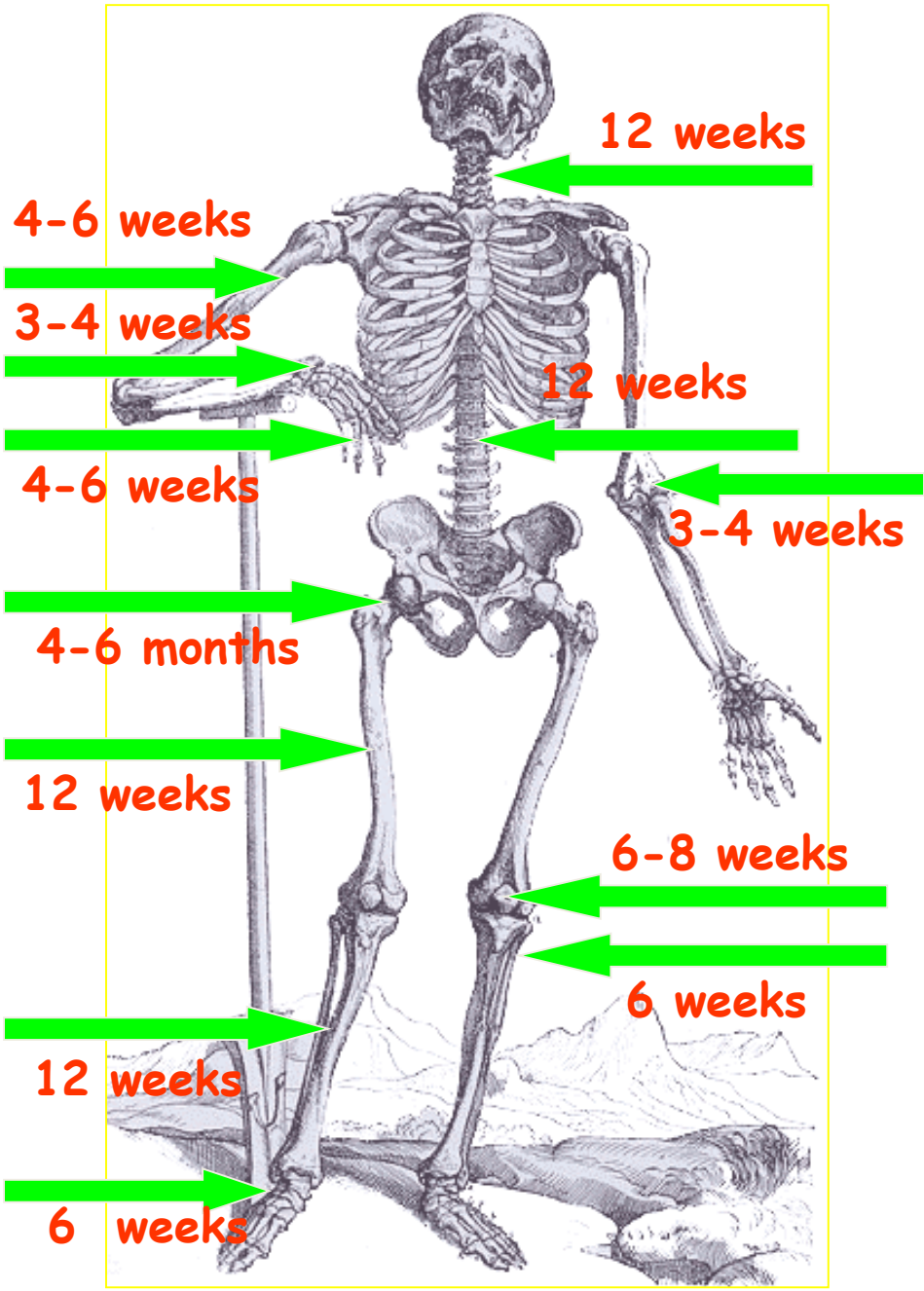


Remodelation in young patient



Healing time of the fractures

- Long tubular bone
  - weight bearing extr.
    - 12 weeks
  - non weight bearing extr.
    - 6 weeks
- Metaphyseal fractures
  - 6 weeks
- Vertebral and pelvic fr.
  - 12 weeks
- Femoral neck fractures
  - 6 months



Delayed bone union

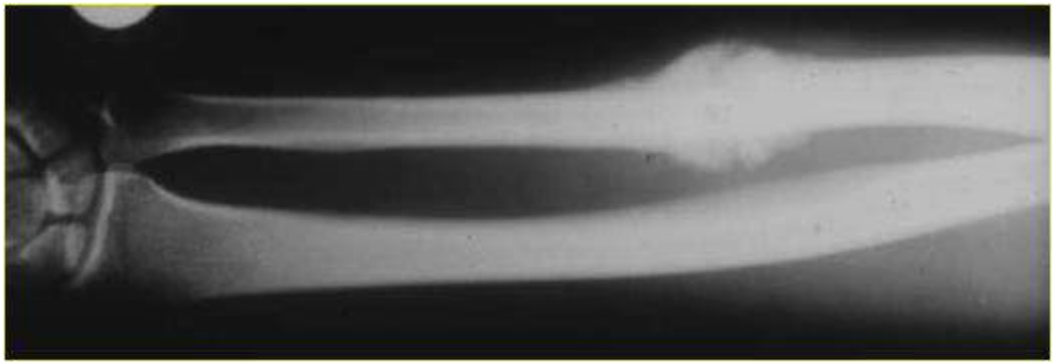
- The bony union of the fracture did not occur
- Probably occur after more immobilization
- Spring effect in the fracture
- Not a final condition

Nonunion

- The bony union of the fracture did not occur
- Terminated condition
- Types:
  - Hypertrophic
  - Atrophic
  - Septic
  - Defect

Hypertrophic nonunion

- Cause: mechanical, not adequate stability
- Good blood supply
- The bone wants to heal
- Callus formations on both end
- Th: adequate stability



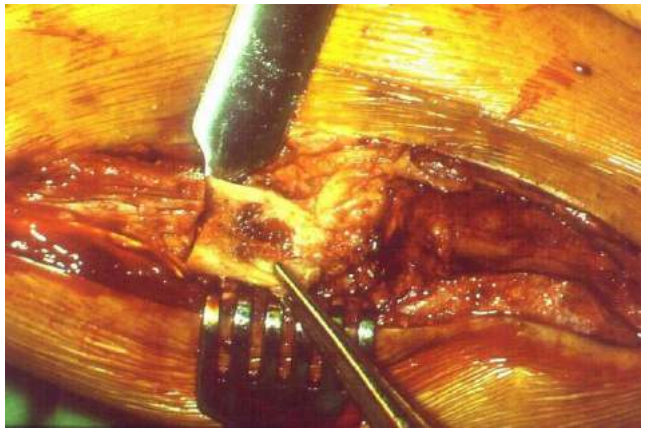
Treatment of a hypertophic humerus nonunion

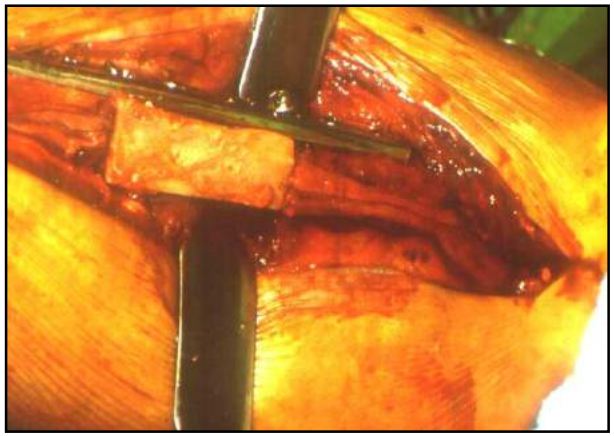


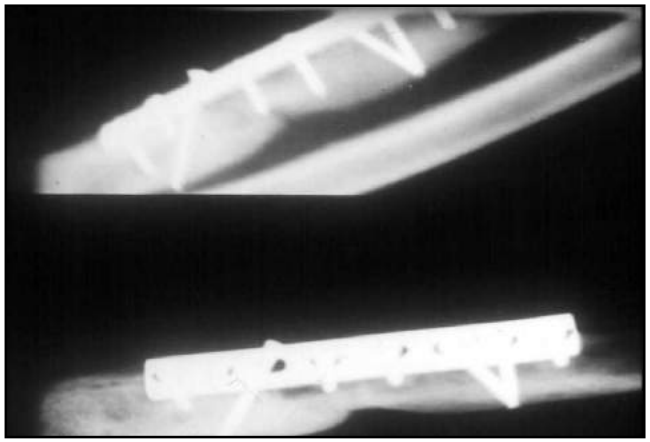

Atrophic nonunion

- Cause: biological, not adequate blood supply
- The bone doesn’t able to heal
- No callus formation
- Th: adequate blood supply

Treatment of an atrophic ulna nonunion



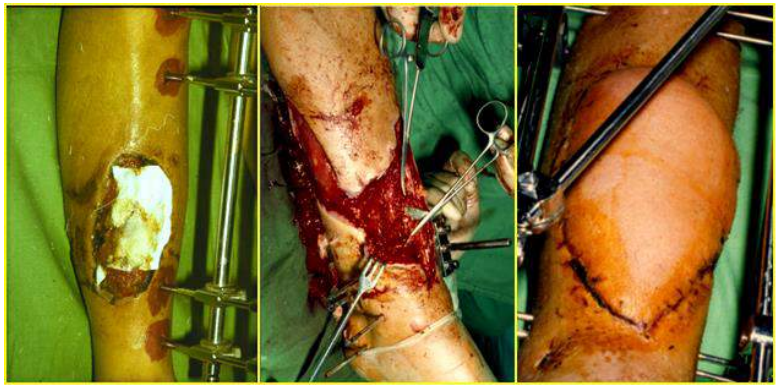


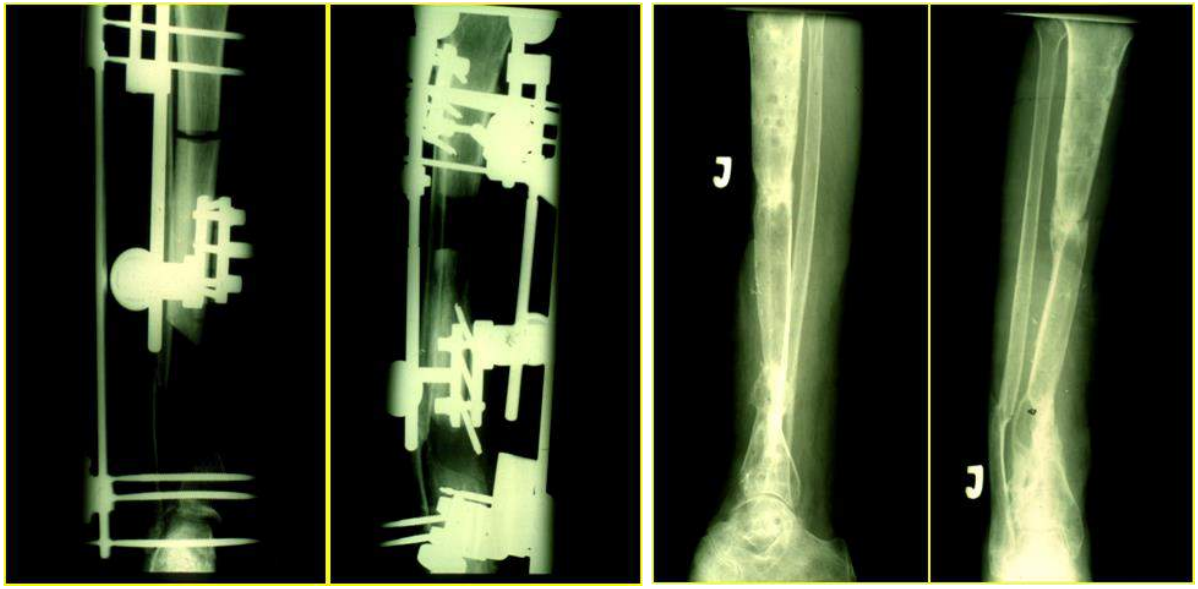


Septic nonunion

- Cause: septic complication
- Inadequate blood supply
- Defect
- Th: treatment of septic complication, soft tissue coverage, bone substitution

Treatment of a septic tibia nonunion





Characteristics and classifications of fractures

Symptoms of fractures

- Absolute
  - Visible bone (Open fracture)
  - Abnormal motion
  - Crepitation (rasping, crack)
- Relative
  - Pain
  - Swelling
  - Loss of function…..

Fracture description, classification

- Anatomical location - ? Joint
- Open or Closed
- Fracture configuration
- Dislocation
- Direct / Indirect
- Simple or comminuted
- Pathological
- Stress fracture
- Greenstick Fracture

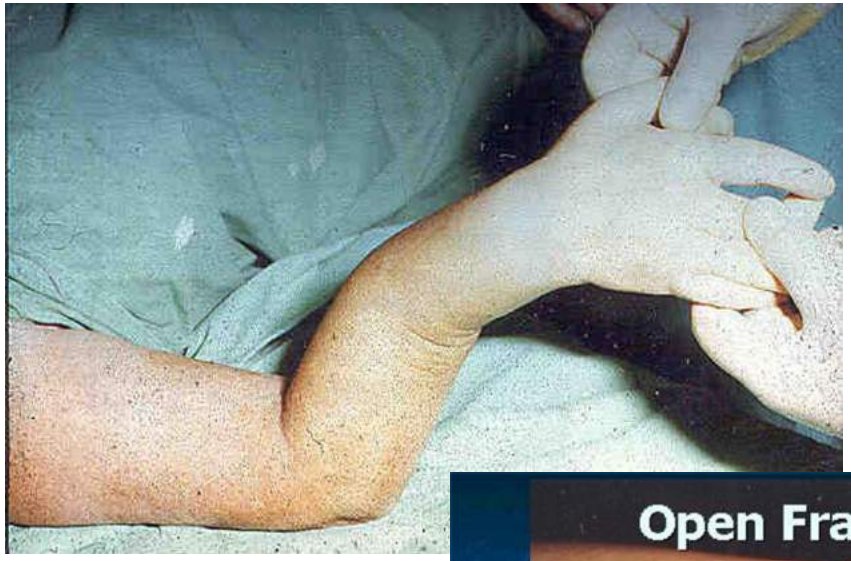
Location

- Diaphysis

- Metaphysis

Closed or open

- Closed



- Open
  - Grade I.
  - Gr. II.
  - Gr. III.

Direction of forces

- Direct

- Indirect

Transverse fracture

Oblique fracture

Short

Long

Spiral fracture

Segmental fracture

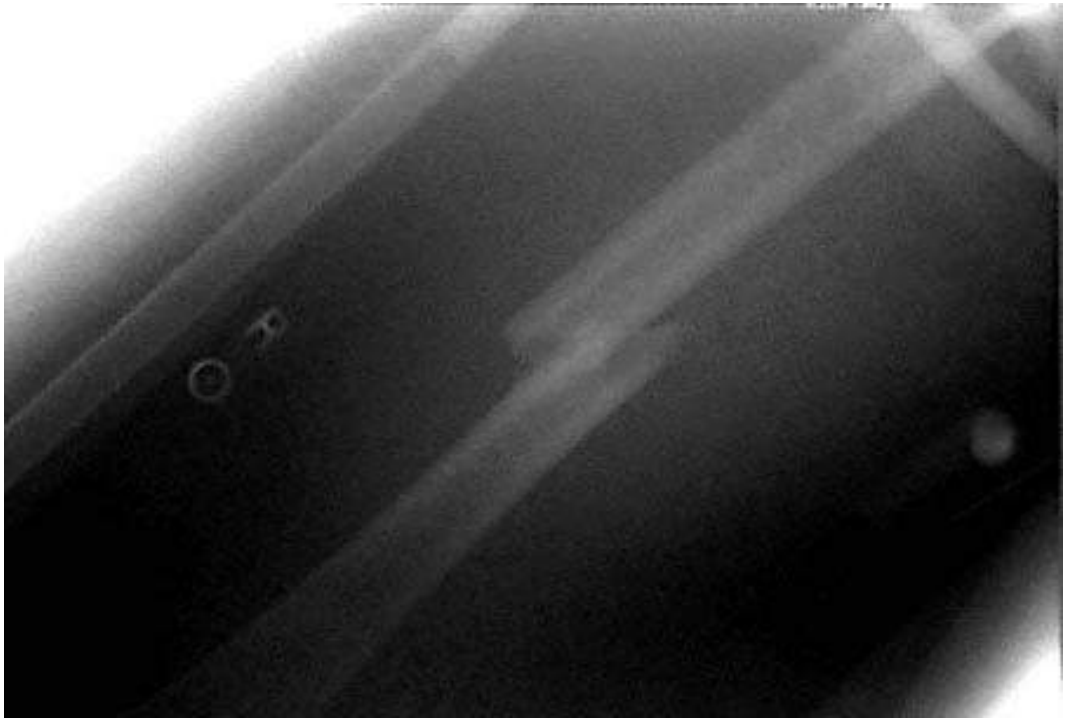
Comminuted fracture

Dislocation

- ad axim
- ad longitudinem
  1. cum contractione
  2. cum distractione
- ad latus
- ad peripheriam

Dislocatio ad axim

Dislocatio ad longitudinem cum contractione



Dislocatio ad longitudinem cum distractione

Dislocatio ad latus

Dislocatio ad peripheriam

Pathological fracture

Greenstick fracture

Dr. Lorenz Böhler:

There is only goal and reason of the reposition of the fractured bone, if it is followed by a proper fixation until the broken bone is healed.

Bőhler's rule:

Who is treating the broken bones?

The body and the nature in itself

What is needed for the nature?

Time.

What is the role of the physician?

After proper reduction to provide the rest of the fracture, and with proper aftercare to provide the proper circulation.

Böhler's three rules:

1. Reduction
2. Retention
3. Rehabilitation

Thank you for your attention!