Bone anatomy and healing

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How to use this handout?

The left column contains the information given during the lecture. The column at the right gives you space to make personal notes.

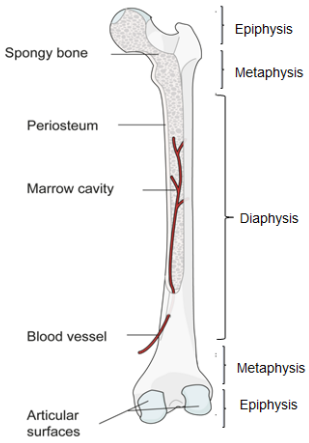
Learning outcomes

At the end of this lecture you will be able to:

- Outline the anatomy of a bone
- Outline the phases of bone healing
- Explain direct and indirect fracture healing
- Identify factors that affect fracture healing

Anatomy of a bone

A **long bone** has:

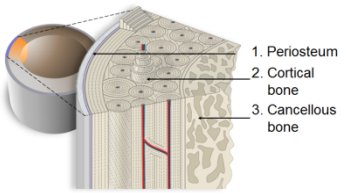


- A compact cortical shaft or diaphysis, (comprising a cylinder of compact bone, its cavity (medulla) being filled with spongy cancellous bone containing bone marrow).
- Terminal portions of the bone with thinner cortices which consist largely of cancellous bone—these are the epihyseal regions forming the articulating parts of the bone, and the metaphyseal areas which link the epiphyseal and diaphyseal parts of the bone.

Diaphyseal bone is organized to create the best balance between weight and structural strength.
The nonarticular surface of the bone is covered by a tough membrane—the periosteum.

The anatomy of the bone will now be considered from the point of view of:

1. The periosteum
2. The cortical bone
3. The cancellous bone

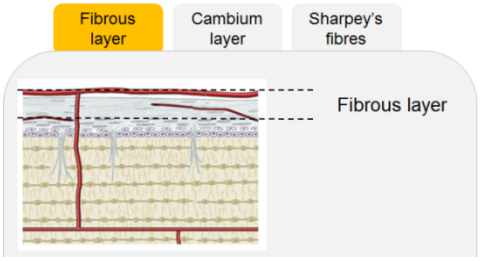


1. Periosteum

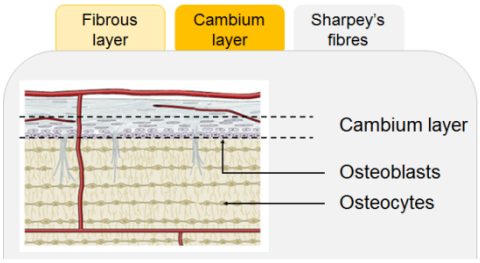
The periosteum envelopes the surfaces of diaphyseal bones, except where they are covered by articular cartilage and where tendons attach.

The periosteum comprises two layers:

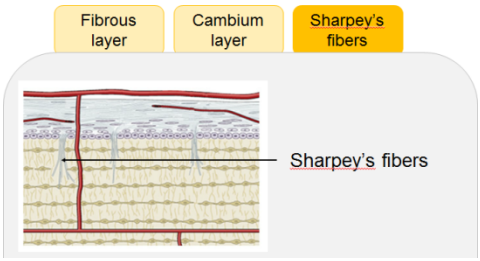
1. The fibrous layer



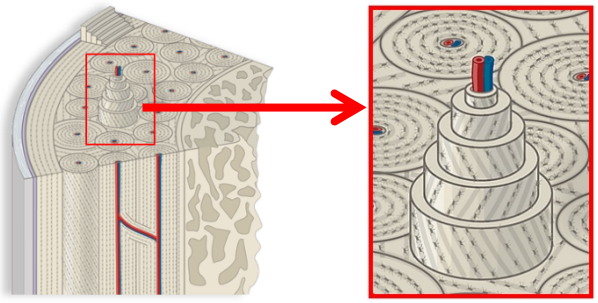
2. The cambium layer



The periost is tightly bound to the bone by the Sharpey‘s fibers.



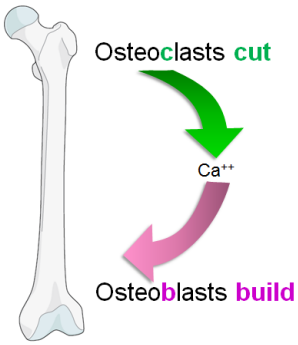
2. Cortical bone—Osteon



An osteon is a basic construction unit also called haversian system. Each osteon has a central canal, containing blood vessels and a small amount of connective tissue with interconnecting channels surrounded by concentric layers or lammellae of bone.
The lamellae are orientated in a helical fashion, each twisting in the opposite direction to its neighbor.
Osteons (haversian systems) run longitudinally in the cortex. The osteons are bound to each other by cement lines. Each osteon is formed around a central vessel.

Bone remodeling

All bone is in a state of constant turnover. Bone is constantly being removed and replaced. This is an essential component of the body's metabolism.
The removal of the bone liberates calcium into the blood stream.

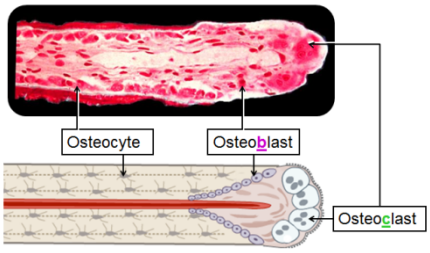


The cells that remove bone are called osteoclasts.

New bone is formed by specialized cells called osteoblasts.
Osteoblasts are derived from mesenchymal precursors and have receptors for the parathyroid hormone, prostaglandins, vitamin D, and certain cytokines. They synthesize bone matrix and regulate its mineralization by capturing calcium ions from the blood stream.

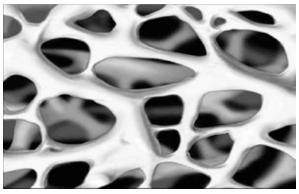
Furthermore, osteoblasts mature into osteocytes, which are the cells of mature bone tissue.

The coordinated actions of the osteoclasts and osteoblasts take place as cutter cones “drill” through old bone and lay down concentric lamellae of new bone to form new osteons. This is revisited in detail later under the topic "direct bone healing".
Whether a cutter cone is taking part in the continuous process of bone turnover, or in bone healing, it functions similarly. Indeed, direct bone healing is accelerated bone remodeling.



3. Cancellous bone

Cancellous (or trabecular/spongy) bone: 20% of its volume is bone mass, less dense, more elastic, and of higher porosity. It is the interior scaffolding of long bone ends and most short bones and helps maintain shape while resisting compressive forces.
Cancellous bone heals faster than cortical bone because of its vascularization leads. Cancellous bone is remodeled by endosteum.



Phases of bone healing (indirect)

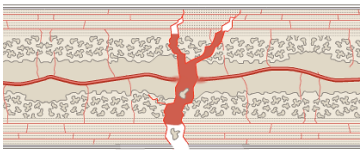
The phases of indirect bone healing are

- Inflammation
- Soft callus formation
- Hard callus formation
- Remodeling

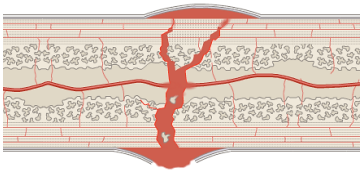
1. Inflammation (1–7 days postfracture)

The fracture results in:

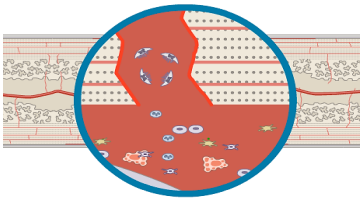
- Soft-tissue damage
- Disruption of blood vessels in bone
- Separation of small bony fragments



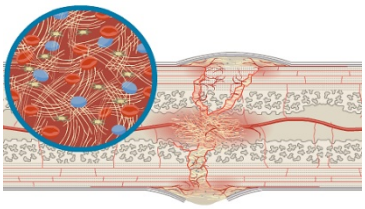
Hematoma forms and the periosteum ruptures partly.



Cells migrate into the fracture hematoma.

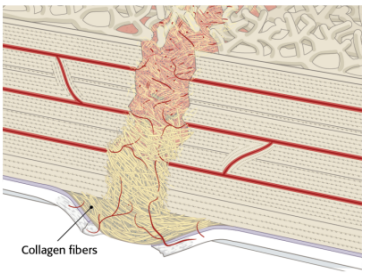


Coagulation starts. Fibrin fibers are formed and stabilize the hematoma (hematoma callus).



2. Soft callus formation (2–3 weeks postfracture)

Once injury occurs, the natural process of bone healing begins with the creation of soft callus—a cascade of cellular differentiation occurs.



Phase 1:

- New blood vessels invade the organizing hematoma
- Decrease of pain and swelling

Phase 2:

- Fibroblasts, derived from periosteum, invade and colonize the hematoma.

Phase 3:

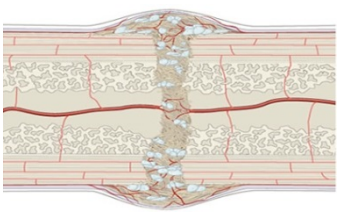
- Fibroblasts produce collagen fibers (granulation tissue).

Phase 4:

- Collagen fibers are loosely linked to the bone fragments.

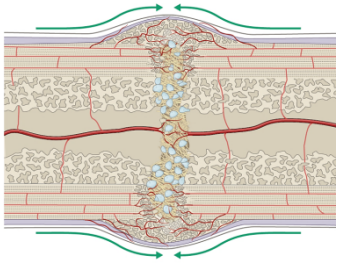
Phase 5:

- The cells of the granulation tissue gradually differentiate to form fibrous tissue and subsequently fibrocartilage (replacing hematoma).



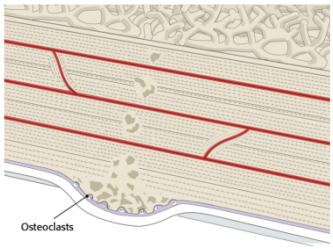
3. Hard callus formation (3–12 weeks postfracture)

Endochondral ossification converts the soft callus to woven bone starting at the periphery and moving towards the center, further stiffening the healing tissue. This continues until there is no more interfragmentary movement.



4. Remodeling (Process taking months to years)

The remodeling stage: conversion of woven bone into lamellar bone through surface erosion and osteonal remodeling once interfragmentary movement ceases.



Fracture healing becomes complete with remodeling of the medullary canal and removal of parts of the external callus.

Fracture healing

Fracture healing is triggered by the breaking of the bone! We often speak of the “personality” of the injury problem.

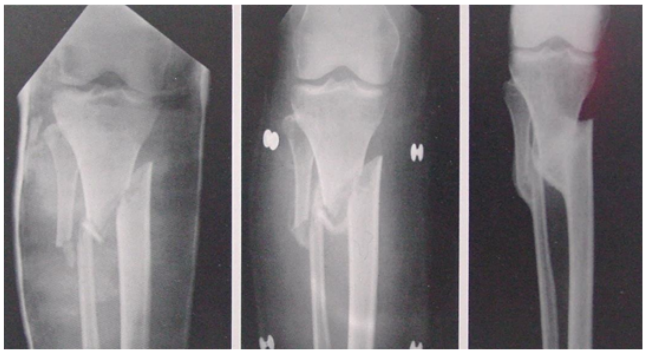
This depends on the factors:

- Complexity of the fracture
- Extent of the soft-tissue injury
- Closed or open injury?
- Periosteal stripping?
- Status of the patient

Indirect fracture healing

Indirect healing occurs when there is still some small interfragmentary motion—a condition called “relative stability”.
It is thought that the interfragmentary motion stimulates callus formation.

However, too much interfragmentary motion can lead to failure of healing—nonunion.



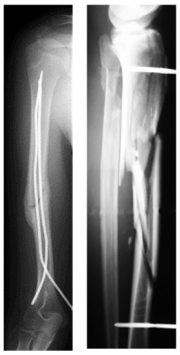
Course of healing:

- Initially hematoma (blood coagulation) is formed between the fragment ends—negligible mechanical properties.
- During the first few days hematoma changes to granulation tissue, which is a little stiffer.
- As the tissue differentiates into more and more stiff forms, so the interfragmentary motion lessens, until it disappears when the hard bony callus bridges the fracture.

Relative stability

Bones heal because they are broken and the most wonderful thing is that they heal without scar formation.

Treatment is needed so that the bone unites in an acceptable position, which permits early mobilization and prevents joint stiffness and deformity.



Nonoperative treatment:

- Reduction
- Cast, splint
- Traction

Surgical treatment:

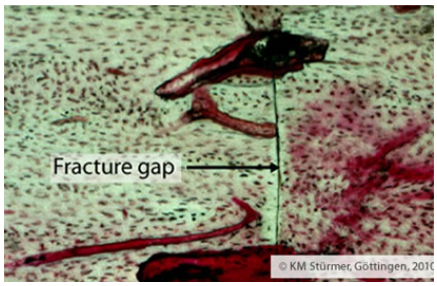
- Intramedullary nailing
- Bridge plating

Direct fracture healing

Direct fracture healing occurs:

- Under conditions of absolute fracture stability
- By direct osteonal remodeling
- Without callus formation

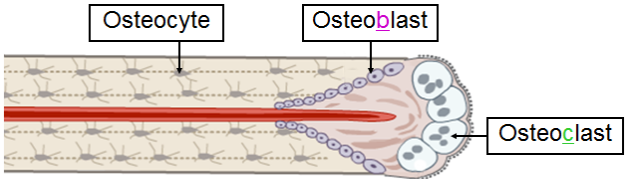
Primary healing occurs even if there is a minimal gap. This is called gap healing.



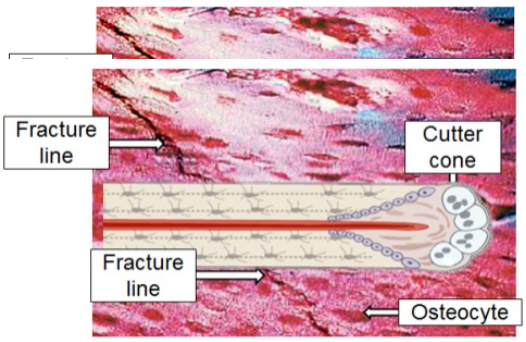
The bone is continually remodeled by cutter cones.

An osteon is a basic construction unit also called haversian system. Each osteon has a central canal, containing blood vessels and a small amount of connective tissue with interconnecting channels surrounded by cocentric layers of bone, the laminae.
There are no osteons in cancellous bone.

- Osteoclasts are present where new bone is being resorbed.
- Osteoblasts participate in the ossification process, present when new bone is formed.
- Osteocytes are trapped within the bone lacunae, is active in the constant remodeling of bone. Lacunae communicate with each other and the canal of the osteons through canaliculae.



Due to the activity of cutter cones, tunnels are cut through the compact bone, resulting in the creation of new haversian osteons in their wake.

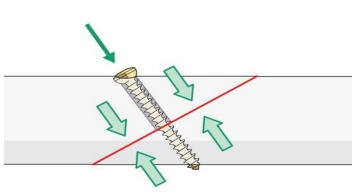


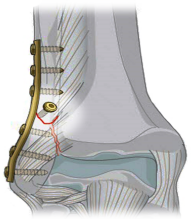
Absolute stability

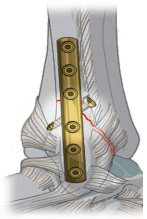
Absolute stability can only be obtained with surgery. The operative treatment depends on the location and the fracture.

Examples are:

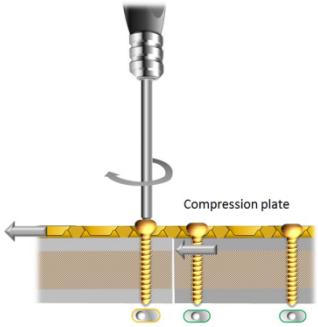
- Lag screw

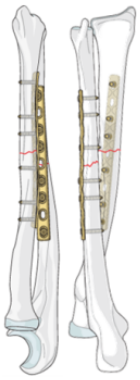






- Compression plate





Factors influencing fracture healing

Factors that affect bone healing include:

- Vascularization of bone fragments, and especially the periosteum
- Soft-tissue conditions

Factors promoting fracture healing

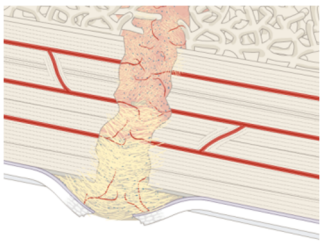
Movement of the limb

- Increases muscle activity
- Stimulates vascularity (venous and arterial flow)
- Stimulates callus maturation
- Prevents thromboembolic complications

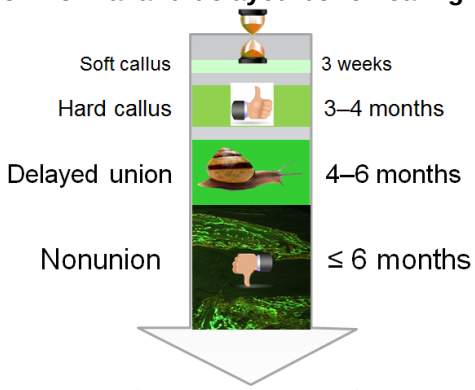
Motion of the limb aids functional recovery, but if it causes strain at the healing fracture site, it increases the risk of tears in the repaired tissue and compromise of callus formation, which is a potential cause of delayed or nonunion.

Factors impeding fracture healing

During the soft callus phase too much movement (excessive strain) risks tears in the repaired tissue and compromises callus formation, which is a potential cause for delayed or nonunion.



Overview on normal and delayed bone healing



Summary

You should now be able to:

- Outline the anatomy of a bone
- Outline the phases of bone healing
- Explain direct and indirect fracture healing
- Identify factors that affect fracture healing

Questions

What is correct? (Cross what is incorrect.)

1. Indirect fracture healing…
    - Induces primary/secondary healing
    - Is always with/without callus formation
    - Occurs in conditions of absolute/relative stability

2. Direct fracture healing…
    - Induces primary/secondary healing
    - Is always with/without callus formation
    - Occurs in conditions of absolute/relative stability

What is the correct answer? More answers can be possible.

1. What are osteoclasts?

- ☐ Bone cells forming the haversian system
- ☐ Bone cells found only in cancellous bone
- ☐ Bone cells involved in the resorption of bone

2. Which factor impedes fracture healing most?

- ☐ Severe damage of soft tissues and the periosteum
- ☐ Early weight bearing
- ☐ Immobilization of the limb

3. Indirect fracture healing…

- ☐ …occurs when relative stability is applied to a fracture
- ☐ …develops when a compression plate is applied to a fracture
- ☐ …appears always in connection with direct osteonal remodeling

Reflect on your own practice

Which content of this lecture will you transfer into your practice?