The Skeletal System

The skeletal system consists of the entire framework of bones and their cartilages. The study of the bone themselves and their structure is osteology.

The **Axial skeleton** consists of the head, neck, spine, thoracic bones.
The **Appendicular skeleton** consists of the bones of the shoulders, arms,

Functions of the skeletal system

- Support of soft tissues
- Protection of internal organs
- Assists in movement; attachment for muscles, provide levers for movement
- Production of red blood cells and some white
- Storage of minerals; especially calcium and phosphate
- Triglyceride (fat) storage

Structure of bones

The skeletal system consists of 206 bones, excluding the auditory bones in the ear (children have more – why?).
Bone is made up of - 20% water, 30-40% organic matter, 40-50% inorganic matter.

Types of Bones (shapes):
There are 5 types of bones

- Long e.g. femur, metacarpals
- Short e.g. carpal and tarsal bones of wrist and foot
- Irregular e.g. vertebra.
- Flat e.g. frontal bone, sternum
- Sesamoid e.g. patella

Development of Bone

Bones start to develop in utero and continue to do so up to the age of 25.

- Long, short and irregular bones develop from cartilage,
- Flat bones from membranes , and
- Sesamoid bones (form within tendons) from cartilage.

First of all osteoblasts secrete Osteoid, which consists of collagen fibres within a
mucopolysaccharide matrix. This gradually replaces the 'parent' tissue. **Ossification** then occurs, when the tissues change into bone
Osteoid may have fibres arranged in two ways:

Non-lamellar bone or woven bone contains fibres arranged in bundles. This occurs in the bones which arise from membranes and in the healing of fractures.

Lamellar bones have fibres arranged in Haversian canals (longitudinally) and Volkmann's canals (radially). Bone cells fall into several categories. They all arise from the same parent tissue, as do
the chondrocytes which form cartilage. Whether cartilage or bone develops depends on the oxygen supply to the tissues, bone formation needing more oxygen.

Bones (structure)

There are at least two types of bone:

- Compact, hard bone – on a microscopic level this contains small spaces which are filled with lymph and osteocytes. The spaces are laid down in repeating concentric circles. This gives the bone great strength. It is found in the shafts of long bones and ribs, and
- Cancellous or trabeculate bone – is filled with red bone marrow, a mass of
- developed and developing red blood cells within a fibrous framework. The bone is made up of a lattice of strands. These strands are not static; they are continuously changing in orientation as bone undergoes constant anabolism and catabolism. It is found at the ends of long bones and in the skull.

Mature compact bone

Bones is a highly organised tissue. This organisation is closely associated with the blood flow and drainage. The basic unit of its structure is the **Haversian system**. The bone intercellular substance consists of collagen fibres embedded in a calcified matrix of calcium phosphate and other salts.

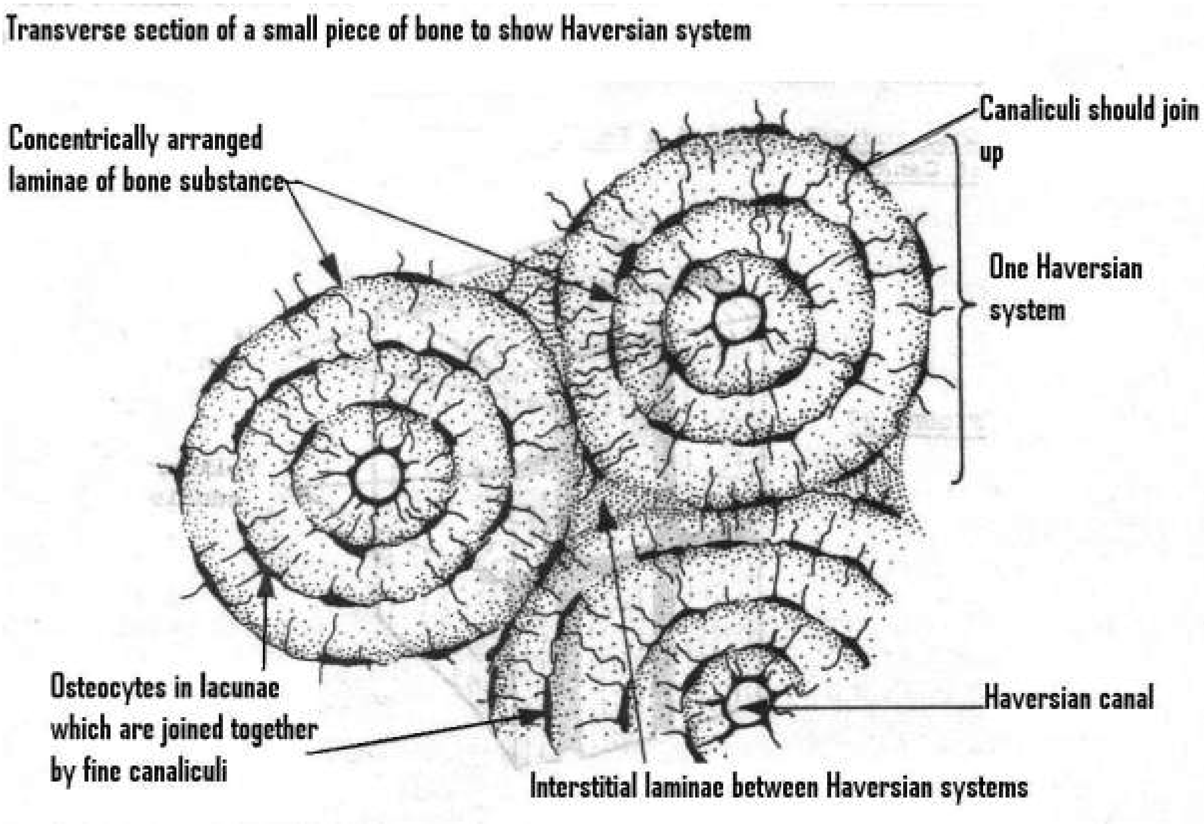
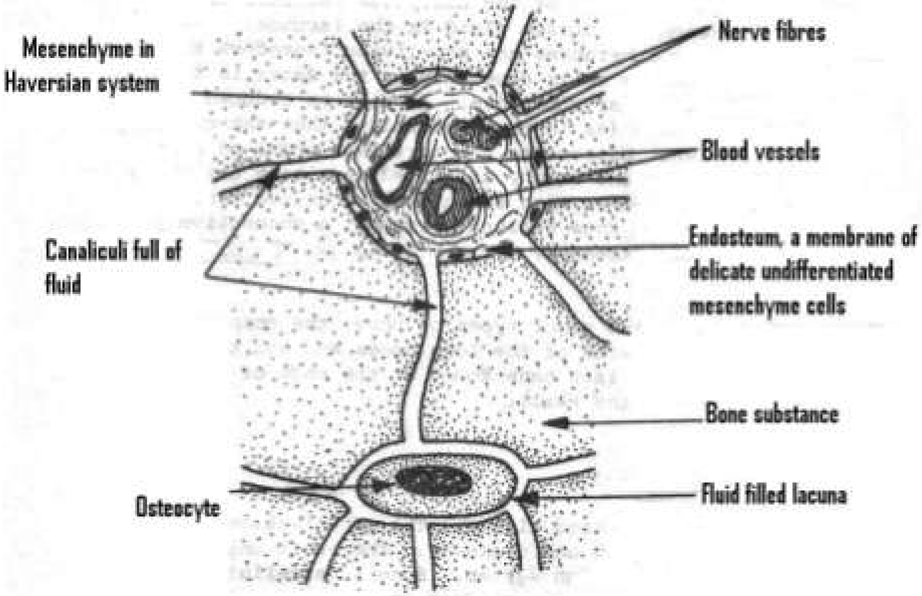


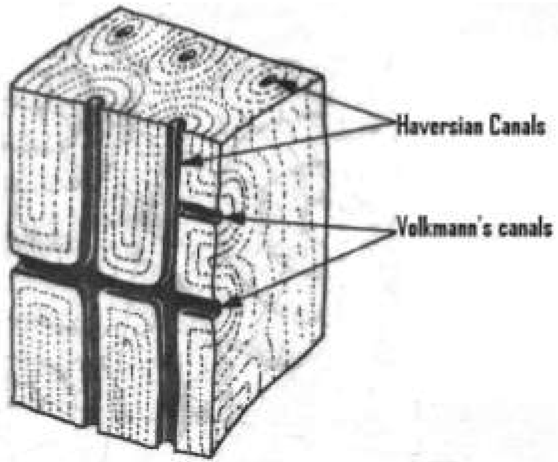
Figure 1 - Cross Section of Bone Showing Haversian Systems

High power transverse section of some lacunae and canaliculi



Haversian canals run longitudinally through bone, the blood vessels of which join up with each other for both supply and drainage via the transverse running Volkmann's canals

Longitudinal view of a small piece of bone showing arrangement of canals

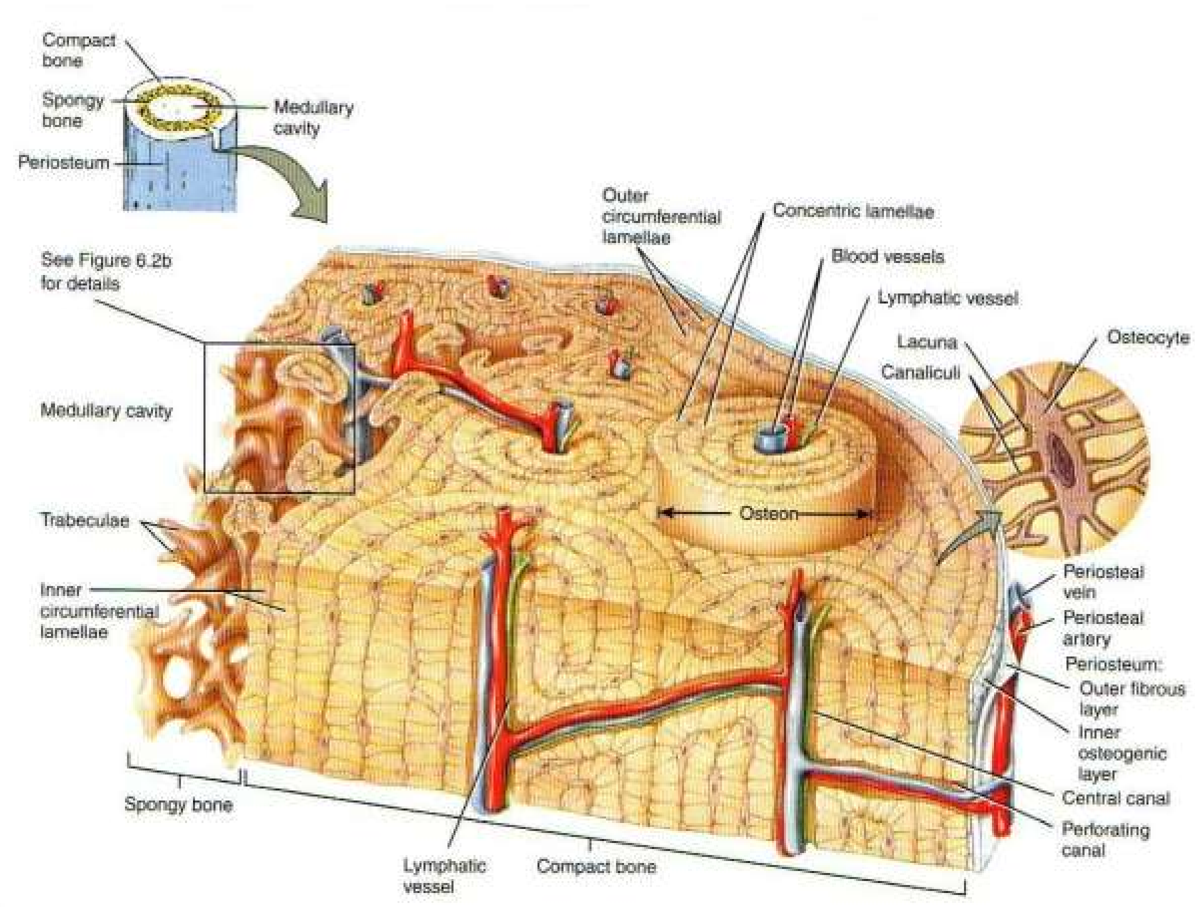


Seeing one of the lacunae close up:

Figure 2 - Close-Up of Bone Showing Lacunae and Canals

Section of Mature Lamellar bone

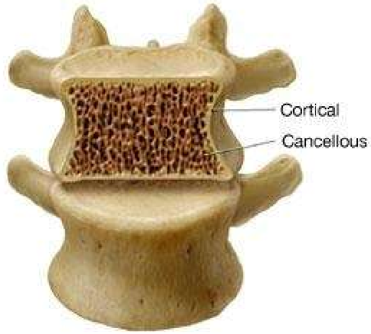
Figure 3 - Section of Bone Showing Osteon and Canals



Bone can be a permanent tissue because the impermeable intercellular substance is permeated with small canals containing blood vessels and lymphatic vessels. Hence bone is highly vascular, whereas cartilage is not.

Cancellous or trabeculate bone

Here the Haversian systems are not so well developed and may seem not to be present at all. The cells here lie in lacunae and are connected with canaliculi to spaces between the trabeculae where there is a vascular system. Hence it has an organisation as compact bone. The trabeculae have an arrangement to give the bone tensile strength along specific lines:



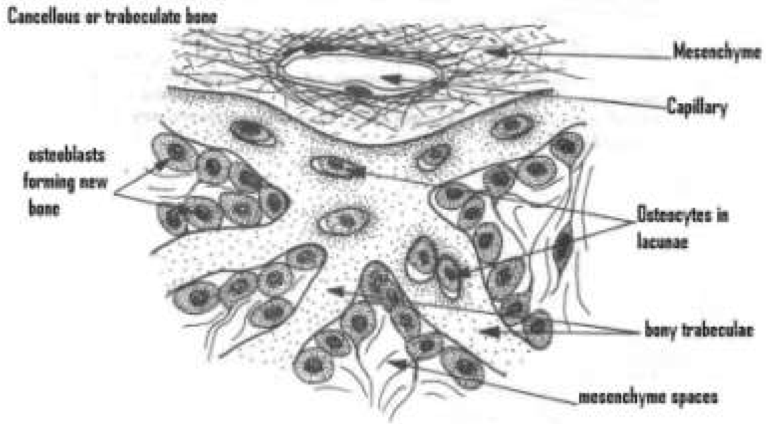


Figure 4 - Cross Section of Trabecular Bone

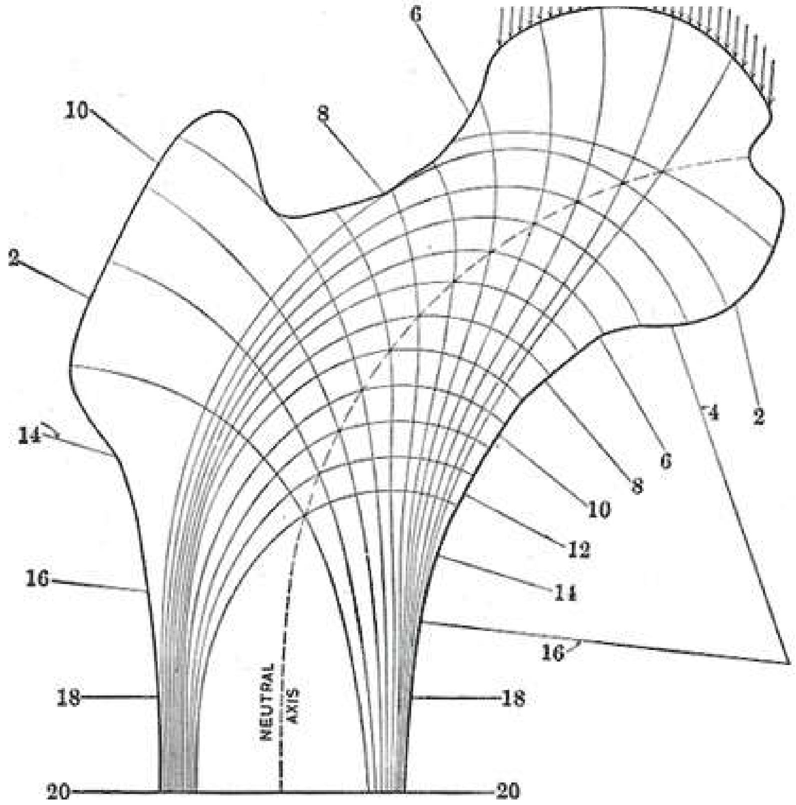


Figure 5 - Section of the Head of the Femur, showing the trabculae and How They Direct and Distribute Forces Through the Bone

Ossification

There are two types of ossification:

a) **Endochondral** – or intracartilaginous, from a cartilaginous matrix model
b) **Intramembranous** – within membrane

Endochondral

Here the bone forms within a cartilaginous model e.g. humerus, femur. In the embryo, hyaline cartilage forms the basic model and, with development, it will be replaced almost entirely by bone. The cartilage is covered by perichondrium. As the vascular system develops in the embryo, blood vessels grow towards the centre of the cartilage model and bone formation is stimulated.

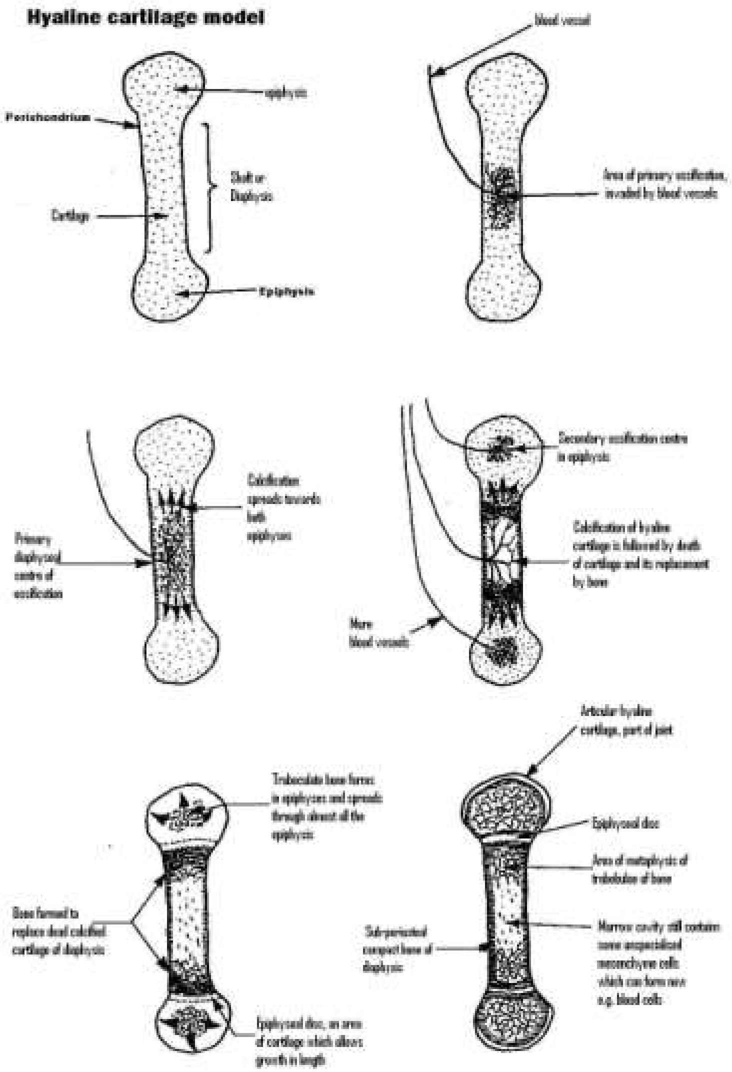
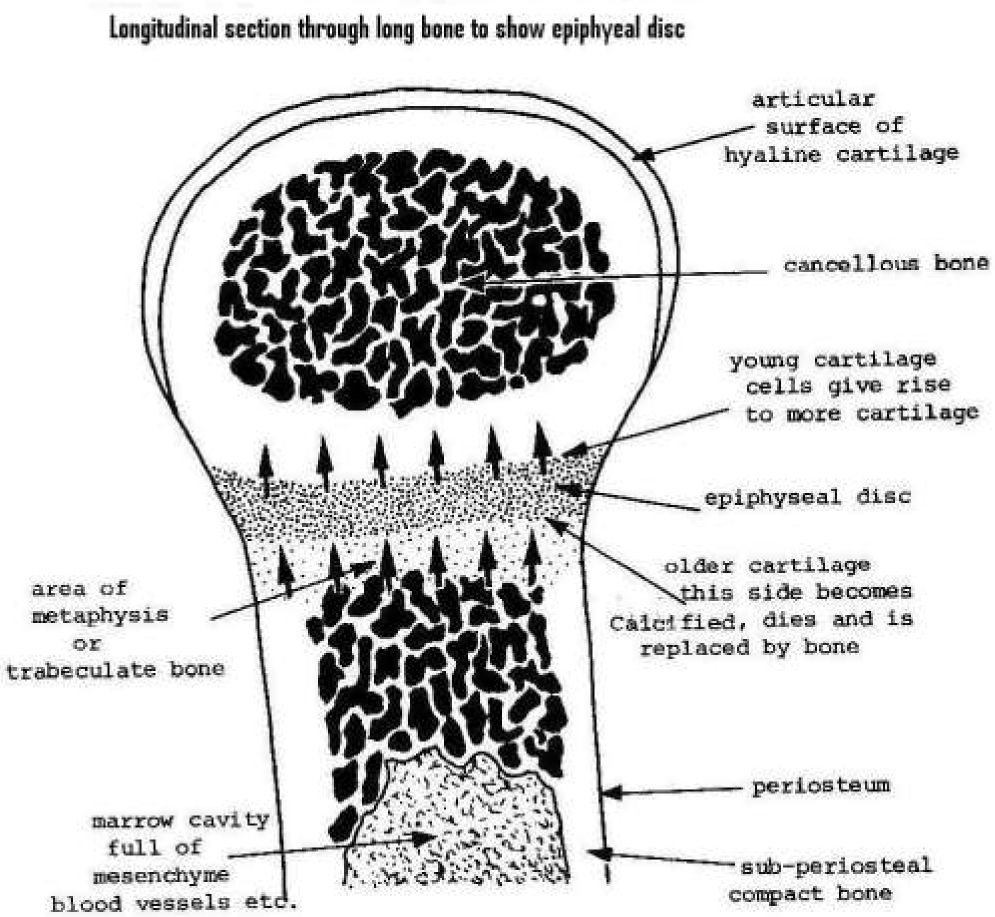


Figure 6 - Diagram Showing the Ossification of Bone from a Cartilaginous Matrix

Hence the sequence of events is:

1. Invasion of cartilage area by blood vessels
2. Calcification and eventual death of cartilage
3. Reabsorption of fragments of cartilage by phagocytic cells. Local production of trabeculate bone
4. Gradual replacement of subperiosteal trabeculate bone by compact bone with Haversian system organ
5. Centre of diaphysis eventually being cleared of bone and filled with red and yellow marrow; red marrow is blood-forming, yellow is fat filled.
6. Gradual growth and remodelling of the bone begins as the muscles function to pull in particular directions.

Bone growth



This takes place in two areas:

- At the ends of (e.g.) long bones (epiphysis) , from activity in the epiphyseal disc
- Increase in circumference from activity of the inner, osteogenic, layer of the periosteum of the diaphysis

Figure 7 - Bone Growth at the End of Long Bones

Cartilage is formed within the epiphyseal disc and is turned into bone.
The modelling of the bones is from the action of the forces on the bone from its
surroundings e.g. the pull from muscles via their tendon attachments.

Intramembranous ossification

This is bone formation where there isn't a cartilaginous model beforehand e.g. the bones of the skull, sternum and ribs.

Bone maintenance

Bone is not a fixed substance, but undergoes constant replacement and remodelling with a continual turnover of osteocytes. All this is in response to the changes of forces to which the bone is exposed. For this to happen there needs to be a supply of calcium, phosphates and carbonates. There are hormones that maintain normal calcium homeostasis in the blood; hormones from the parathyroid and Calcitonin from the thyroid gland. These, along with vitamin D, affect calcium absorption form the gut and excretion via the kidneys.

Bone, like skin, forms before birth but continually reforms itself. Even after reaching their adult size, old bone is being continually destroyed and new bone is laid down. This is called remodelling; it occurs as a continual process or in the occasion of fracture Maintenance and repair of bone tissue is carried out by specific cells:

Osteoblasts occur in the deeper layers of periosteum, ossification centres of immature bone: the diaphysis and epiphyses, and at fracture sites. As they become trapped in the developed bone they stop dividing to produce new cells and become osteocytes.

Osteoclasts occur under the periosteum, to maintain the shape of the bone and remove excess callus formation at fracture sites, and also round the walls of the medullary canal in the centre of the long bones to maintain the correct ratio of canal to lamellar bone. They control resorption.
Both osteoblasts and osteoclasts are not only active in growth and normal bone homeostasis; they are also active in healing. If there is a fracture of a bone, the fracture will disrupt the blood flow through the bone, causing death of bone tissue adjacent to the fracture site. Here osteoclasts reabsorb the dead bony tissue, whilst osteoblasts lay down new bone tissue.
This normal metabolism is dependent upon several factors, including: 1) adequate minerals, especially calcium, phosphorus and magnesium, 2) vitamins A, C and D, 3) several hormones and 4) weight bearing exercises.

The structure of bone consists of:

- The **diaphysis** (growing between) – the main body or shaft of the bone
- The **epiphysis** (growing on or over – the distal, or proximal ends of the bone
- The **metaphysis** (meta=between) – the region in a mature bone where the epiphysis joins the diaphysis
- The **articular cartilage** – the thin layer of hyaline cartilage over the end of the epiphysis that forms an articulation with another bone
- The **periosteum** - the dense sheath of irregular connective tissue that wraps around the one where it isn't covered with hyaline cartilage
- The **medullary cavity** – or marrow cavity, is the space in the diaphysis fat or Haemopoietic cells
- The **endosteum** (endo=within) – a thin layer of cells that line the marrow cavity. It contains single layer of osteoblasts

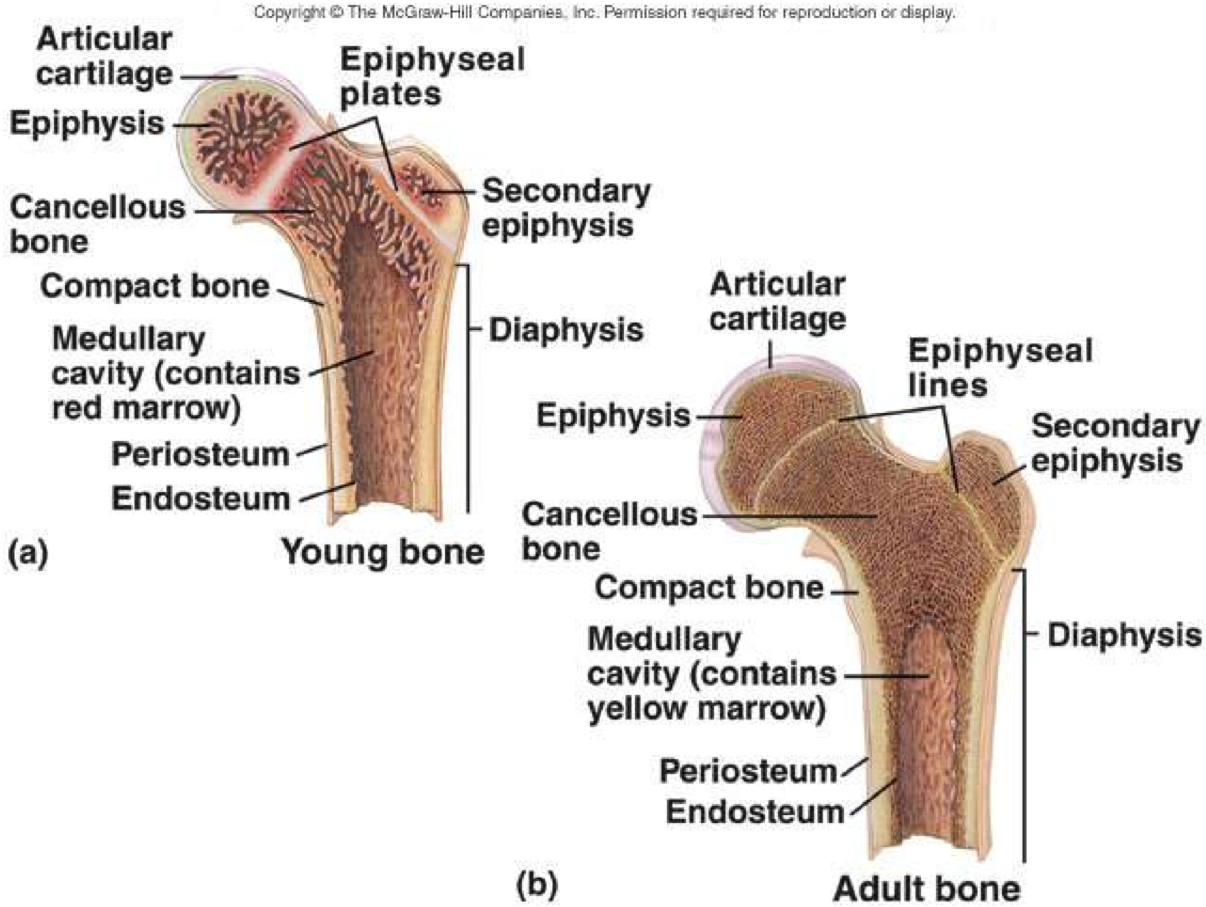


Figure 8 - Diagram Showing Regions of Long Bone

Disorders of Bones:

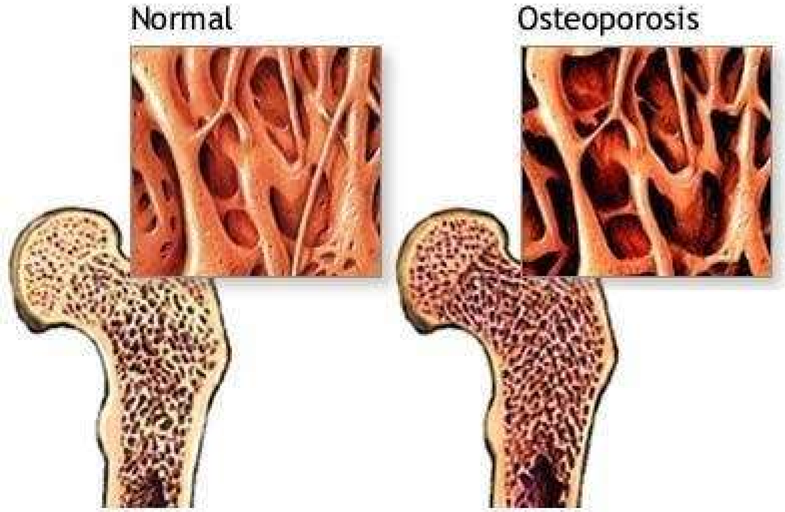


Figure 9 - Bones: Normal Compared With Osteoporosis

Osteoporosis - a reduction of bone mass due to the rate of deposition being out stripped by reabsorption. It may be progressive or reversible depending on the cause. Cancellous bone is more easily affected.

Localised osteoporosis may occur when a bone is immobilised due to a fracture, paralysis or conditions such as arthritis (see below).

Prolonged generalised immobility may lead to the reabsorption of calcium causing kidney stones and this can lead to renal failure.

Generalised osteoporosis seems to be due to hormonal fluctuations and is therefore more common in women than men.

It often happens post- menopause or can happen in female athlete's who's hormonal balance is disturbed due to excess reduction of body fat, leading to under production of oestrogen. There is evidence to suggest that too high a level of protein in the diet can lead to osteoporosis in later life. The balance between oestrogens/ androgens and glucocorticoids also seems important.

Fractures:

- **Simple** (a clean break),
- **Comminuted** (several fractures in the same region),
- **Compound** (protrudes from the skin)
- **Green-stick** (more frequent in the softer immature bones and like the break of a green twig).
- **Stress** (repetitive activity producing healing e.g. metatarsals)

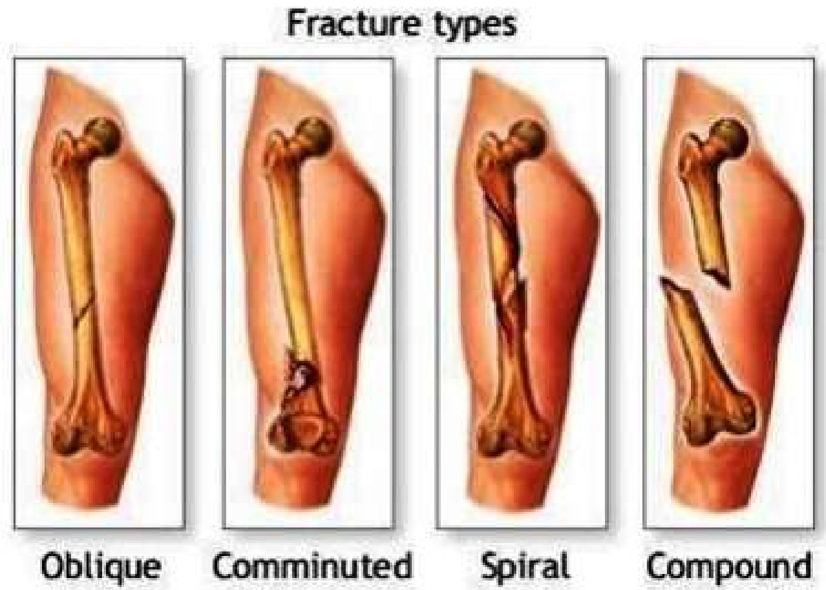


Figure 10 - Common Types of Fracture

Ricketts –this is due to vitamin D deficiency. Vitamin D is important in children for the absorption of Calcium from the gut; hence it occurs in children resulting in the bones being softer and causing them to be bowed. A similar condition in adults is called osteomalacia, due to incomplete ossification or defective deposition and reabsorption.

Figure 11 - Ricketts

Osteomyelitis- microbial infection of bone due to fracture, spread from an abscess, surgery or infection via the blood.

The bone may become necrotic or filled with pus or an abscess may form with a sinus which drains through the skin. The condition may resolve and heal completely. Alternatively the infection may become chronic, with delayed repair or the infection may spread into the joints or the blood.

Tumours

Bone tumours may be malignant, as is shown here with an osteogenic sarcoma with its characteristic 'sunrise' appearance

Figure 12 - Pictures Showing: Osteosarcoma and Osteoid Osteoma

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Benign tumours, like this osteoid osteoma, can challenge the bones' local integrity