DEV 2022 – Anatomy and Development

The Human Body Plan

Four Tissue Types

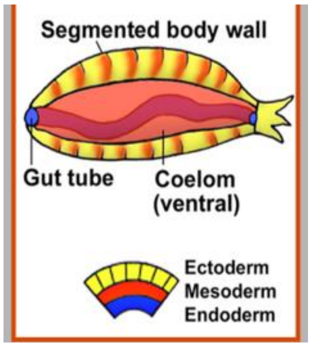
1. Epithelia
2. Connective (bone, cartilage, loose, dense regular, dense irregular, adipose and blood and vessels
3. Muscle (cardiac, smooth, skeletal)
4. Nervous System

Kingdom – Animal

- A living organism capable of independent movement
- Surrounded by a cell membrane
- Contains organelles
- Derives energy from organic foods and oxygen

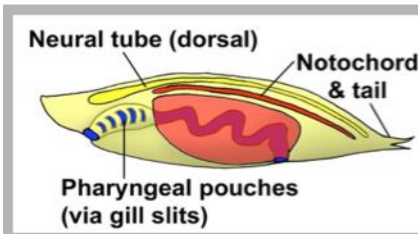
Superphylum – Coelomate

- Segmented body wall (for greater movement)
- Coelom (fluid-filled internal body cavity)
- Gut tube is suspended in the coelom



Phylum – Chordate

- Notochord (flexible rod of support)
- Neural tube (dorsal hollow nerve cord)
- Polarity (head and tail)
- Gill slits (transient)

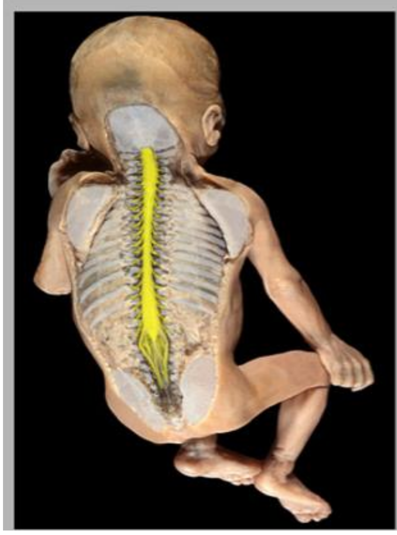


Segmentation – Dermatomes and Myotomes

- Clear pattern in trunk
- More stretched over limbs
- Cranial nerves 1-12 are segmented

Polarity – Cephalisation

- Cranial (head) and caudal (tail) end
- Special senses and start of gut tube at cranial end

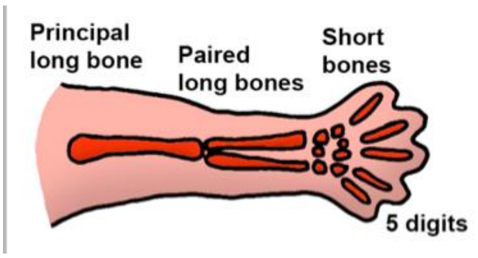


Subphylum – Vertebrate

- Notochord during development
- Vertebral column
- Heart pumping blood under pressure
- Head with special sense organs
- Four limbs and 5 digits (terrestrial transition)

Pentadactyl Limbs

- Each limb develops with principal bone proximally, a pair of long bones distal to it, then short bones and 5 digits



Musculoskeletal System

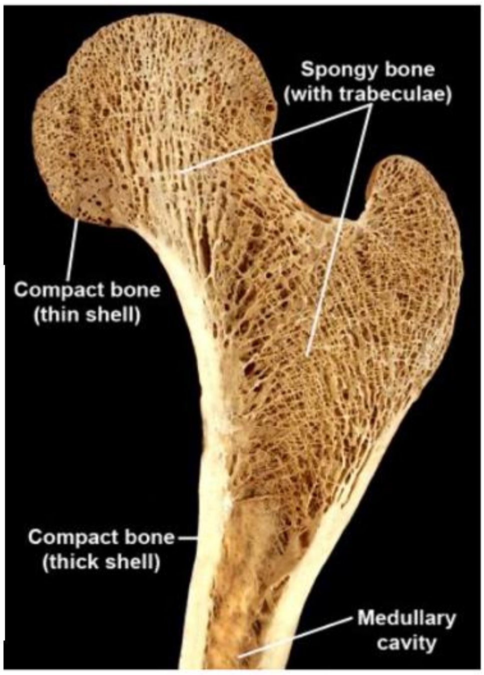
Composition

Extracellular Matrix

- Mineralised ground substance (otherwise soft)
- Collagen fibre reinforcement (otherwise brittle)

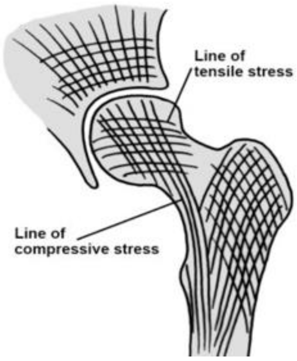
Types

- Compact bone
- Cancellous (spongy bone with trabeculae)
- Medullary Cavity



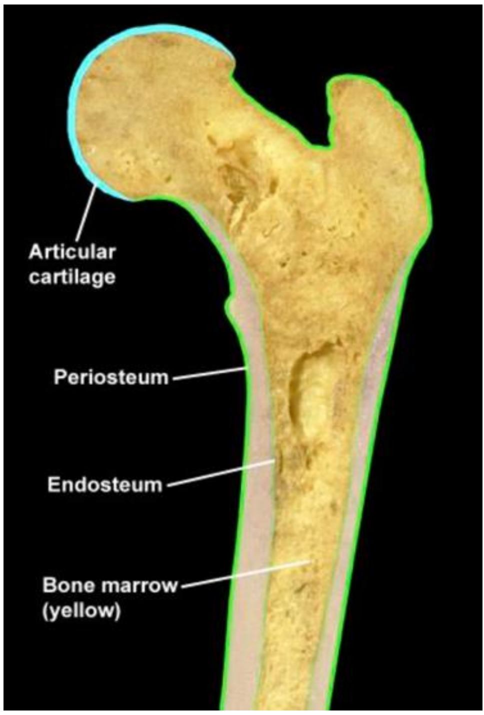
Bony Trabeculae

- Bony trabeculae are oriented along lines of stress
- Lay along compressive and tensile fibres



Periosteum

- Membrane around the outside of the bone
- Highly innervated
- Only articular surfaces are not covered by periosteum



Types of Bone

- Long
- Short
- Flat
- Irregular

Also

- Pneumatic, Sesamoid and Accessory

Bony Parts and Features

- Articular surface (At Joints)
- Ends and Shaft (of Long Bones)
- Bony features (elevations from traction on periosteum)
- Bone markings (grooves from tendons, nerves and vessels)

Cartilage

Is <u>avascular</u> and <u>aneural</u> and doesn't require a blood supply as diffusion can occur

Hyaline – Glossy/Clear and rich in Hyaluronic Acid

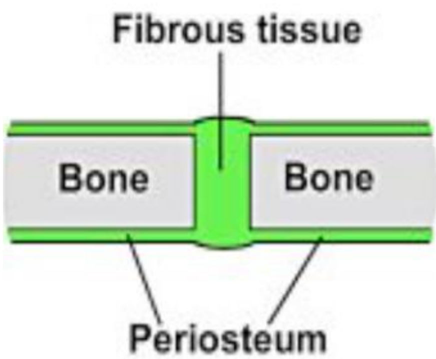
Fibro – Found in the vertebral column

Elastic – Found in the ear

Articular System

Fibrous Joints

- Bones are bridged by fibrous tissue
- Solid joint with no joint cavity
- Permit no movement
- Allow for growth
- Found in the skill and around teeth

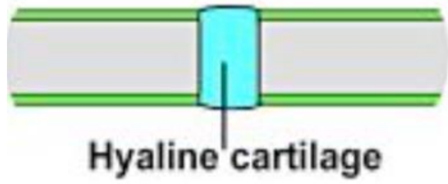


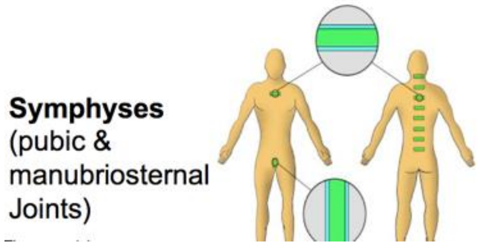
Primary Cartilaginous Joints

- Bones are bridged by cartilage
- Solid joint with no cavity
- Permit almost no movement
- Allows for growth
- Withstands pressure
- Found in Costochondral joints and Epiphyseal plates

Secondary Cartilaginous Joints

- Bones are bridged by **fibrocartilage** between **hyaline** cartilage
- Solid joint with no cavity
- Permit restricted movement
- Located exclusively in body midline
- Found in intervertebral discs
- Symphyses (pubic and manubriosteral joints



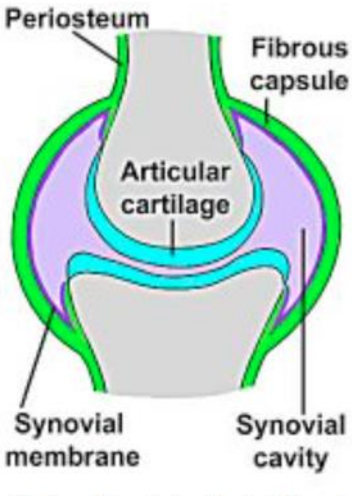


Synovial Joints

Most common type of joint and allows for extensive

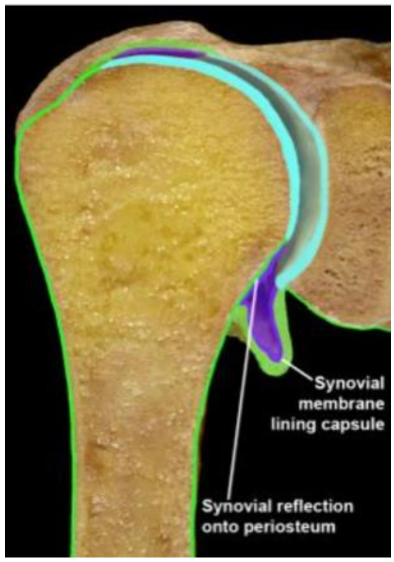
Features

- Joint cavity
- Articular cartilage
- Fibrous capsule
- Synovial membrane
- Synovial fluid
- Ligaments



Synovial Joint Cavity

- Interior joint space
- Volume is normally small
- Most joints have a single joint cavity
- Some cavities are partly and completely subdivided
- Can contain 2 joints



Synovial Joint Classification

Can be classified by their number of articular surfaces

Simple

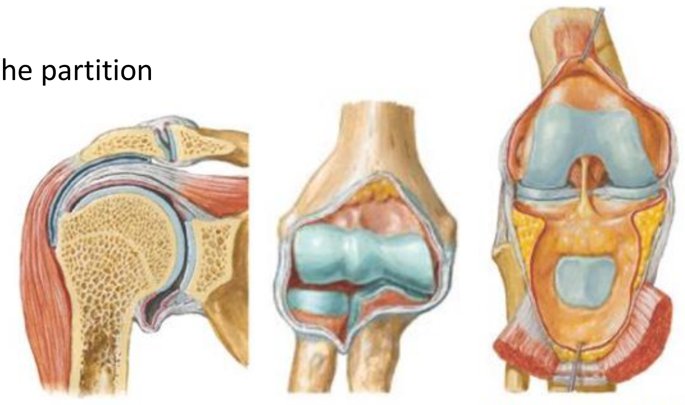
- One pair

Compounds

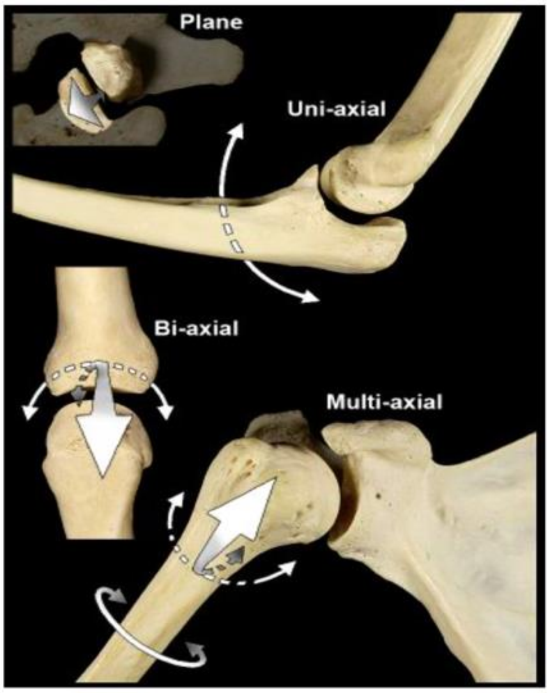
- More than one pair (elbow)

Complex

- Subdivided into more than one compartment (Knee)
- Complete or incomplete partition
- Enables separate movements to occur either side of the partition



Synovial Joint Types



Determined by the shape of **articular surfaces**

Plane – moves in one axis

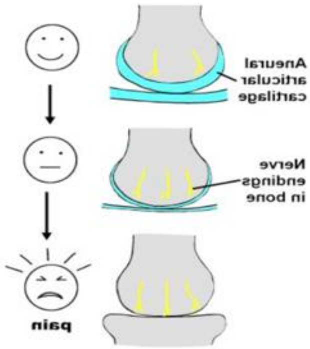
Uni-Axial – 2-way movement (hinge joint)

Bi-Axial – Moves in four planes

Multi-Axial – Rotates (shoulder)

Articular Cartilage

- Lines articular surfaces
- Withstands compression by reducing friction
- Tends to degenerate
- Nerve endings in bone causes pain when it is degraded as they run together



Fibrous Capsule

Capsular Ligament

- Dense connective tissue enclosing synovial joints
- Attaches to articular margins
- Defines joint boundaries

Synovial Membrane

- Serious membrane (single layer of flattened cells)
- Lines internal surface of the capsule
- Also lines all non-articular structures in the joint
- Does not extend over articular cartilage
- Receives rich blood supply
- Secretes synovial fluid into joint cavity

Synovial Fluid

- Acts as a lubricant for articular cartilage
- Viscosity decreases with loading
- Can causes synovial effusion = when cartilage is irritated and accumulates
- This can cause pain, swelling contained by the synovium, pus and blood

Ligaments

- Fibrous connections between bones
- Mainly collagen
- Blend with periosteum
- Contain nerve supply
- No blood supply
- **Intrinsic –** Reinforce capsule
- **Extrinsic –** Separate from capsule
- **Collateral Ligaments** – Side of hinge joints
- **Accessory Ligaments** - Away from joint

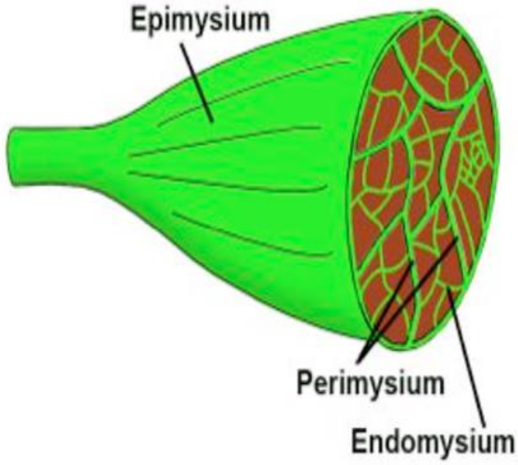
Joint Structures

Labrum – Fibrocartilage Deepens joint socket
Disc – Fibrocartilage – subdivides joint cavity
Meniscus (fibrocartilage) – Partially subdivides joint cavity
Intracapsular Tendons – Tendon
Bursae
Fat Pads

Skeletal Muscle

- Moves bones
- Each fibre is a discrete unit
- Multiple peripheral nuclei

Skeletal Muscle Cells
Fibres are soft and fragile



Connective Tissue

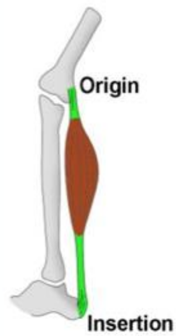
- Forms fibrous sheaths around muscle
- Supports and protects muscle cells
- Provides neurovascular supply

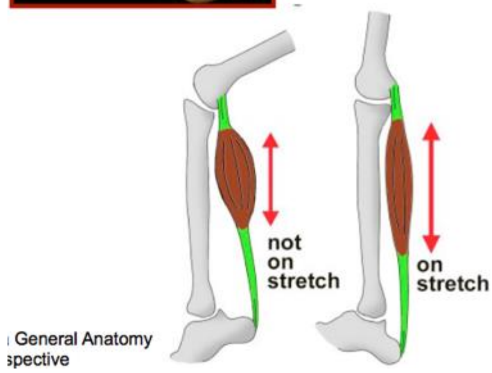
Epimysium – Surrounds the whole muscle
Perimysium – Surrounds fascicules (bundles) of muscle fibres
Endomysium – Surrounds individual muscle fibres (thin)

Muscle Attachments

Origin is typically fixed and **more proximal**
Insertion is typically mobile and **more distal**

- Can be one or more heads of origin and tends of insertion
- Muscle crossing more than on joint are particularly prone to injury





The Origins of Skeletal Tissue

Three Lineages of the Skeleton

Axial Skeleton

- Paraxial mesoderm – Sclerotome

Appendicular Skeleton

- Lateral plate mesoderm

Cranial and Facial Bones

- Cranial neural crest cells migrate into branchial arches and craniofacial bones and cartilages

Four Bone Cell Types

Osteoprogenitor cells – Precursor cells that self-replicated or differentiate into bone forming cells
Osteoblasts – Bone forming cells that secrete osteoid (mineral matrix)
Osteocytes – Mature bone cells found in the lacunae
Osteoclasts – Macrophage type cells that resorb bone in remodelling

Intramembranous Ossification

Gives rise to

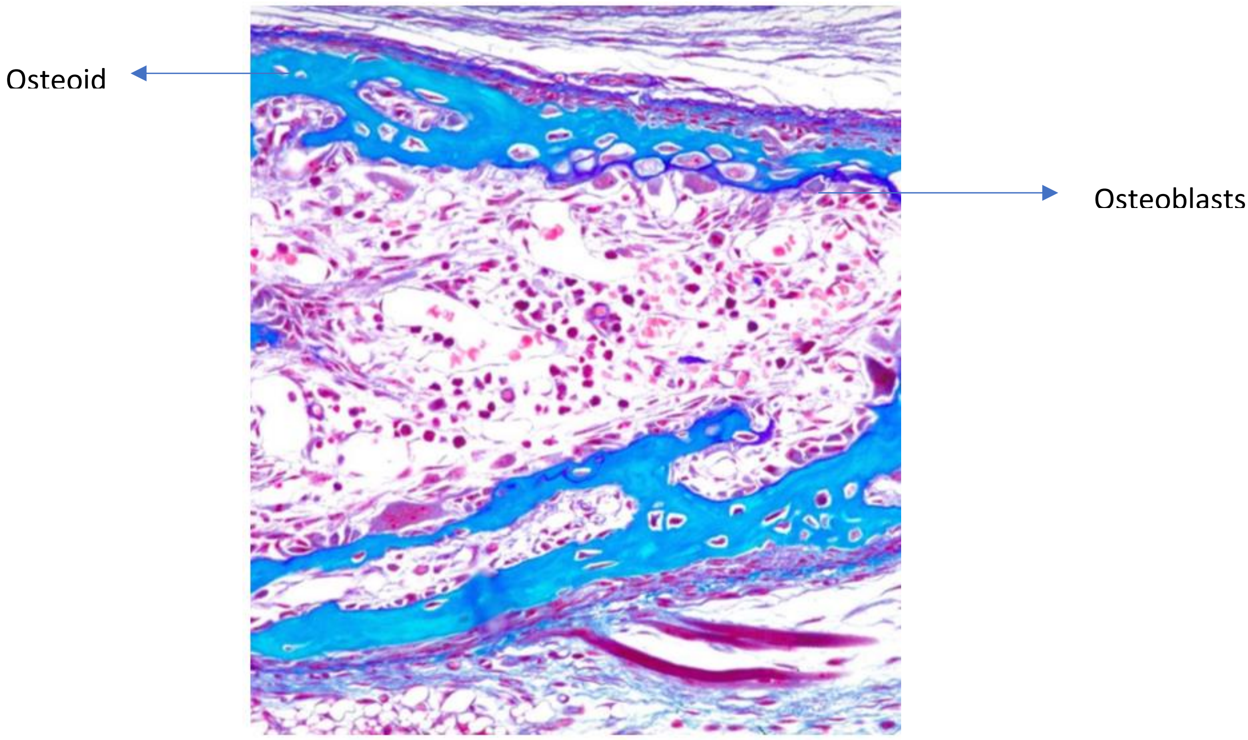
- Frontal Bone (Skull)
- Parietal Bones (Skull)
- Parts of occipital and temporal bones
- Maxilla, mandible and clavicle

Contributes to

- Growth of short bones
- Thickening of long bones

Process

- Groups of mesenchymal cells differentiate into osteoblasts
- New bone matrix (osteoid) is formed and calcified
- Osteoblasts become trapped in bone matrix (sit on sides)
- These become osteocytes
- Islands of developing bone are known as spicules
- Numerous ossification centres
- Connective tissue between spicules contain blood vessels and haemangioblast
- Bony spicules fuse
- Fontanelles in developing skull bones are areas of CT that have not yet ossified – used in birthing
- In flat bones of the skill, two layers of compact bone form, whereas central portion maintains its spongy bone nature

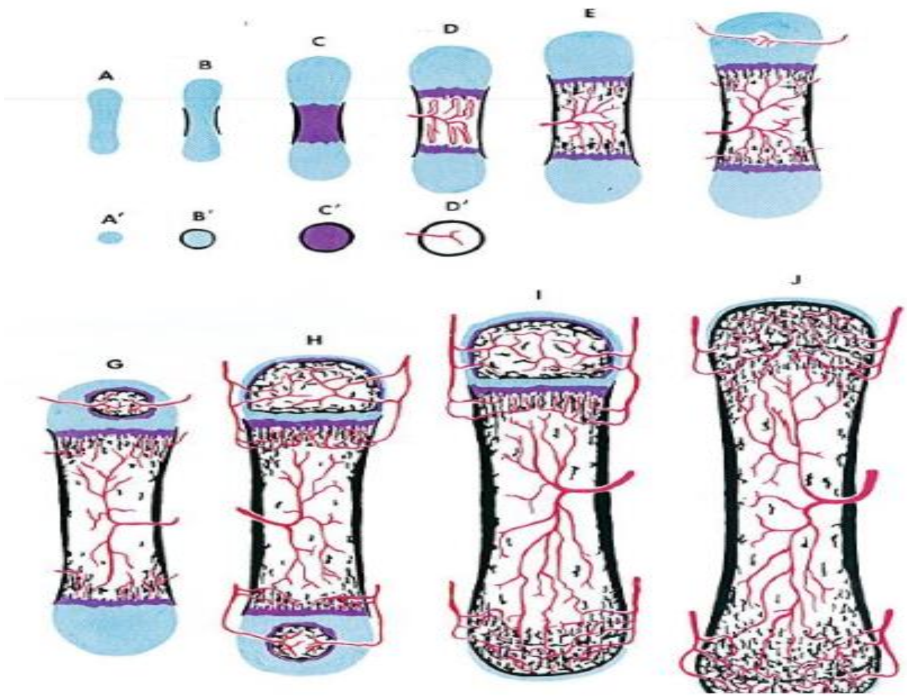


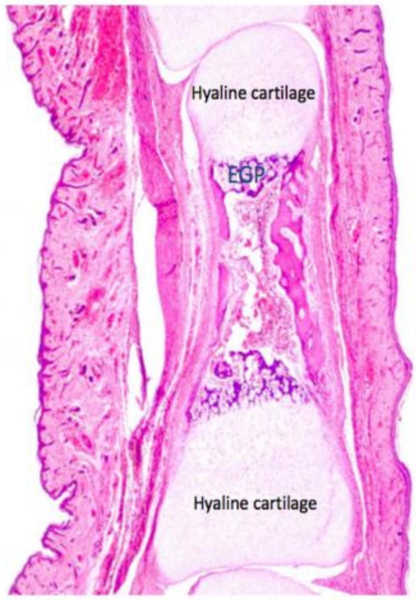
Endochondral Ossification

- Occurs within a piece of hyaline cartilage
- Hyaline cartilage is replaced by bone
- The cartilage DOES NOT TRANSFORM – IT REPLACES IT
- Forms short and long bones

Process

1. Hyaline cartilage model with perichondrium
2. Chondrocytes in the mid-shaft region begin to hypertrophy as the periosteum (black) is deposited around the midportion of the shaft
3. The region of hypertrophied chondrocytes becomes calcified (purple) and the chondrocytes die
4. Blood vessels from surrounding connective tissue grow into diaphysis and invades the spaces left by the dead chondrocytes
5. The blood vessels grow towards each end of the cartilage model. Pluripotential stem cells are carried in with the blood and ultimately give rise to bone marrow or differentiate into osteoblasts which lie on the irregular spicules of calcified cartilage matrix. Osteoblasts begin to deposit bone matrix (black)
6. Blood vessels and mesenchyme enter the upper epiphyseal cartilage
7. The epiphyseal (secondary) ossification centre develops
8. A similar ossification centre develops in the lower epiphyseal cartilage. Upper and lower epiphyseal growth plates are now evident
9. The lower epiphyseal growth plate disappears
10. The upper epiphyseal plate disappears – Cartilage is now only present at articular surfaces





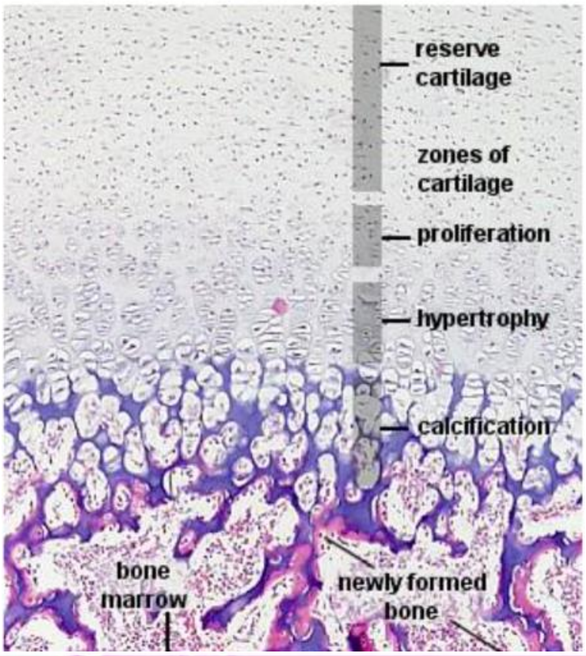
Growth in Length of Long Bones

Epiphyseal Growth Plate

- Connects the epiphysis to the diaphysis
- Is responsible for the growth in length of long bones
- At the end of puberty, the growth plates disappear and bone lengthening can no longer occur
- Thickness of growth plate remains constant
- Due to rate of proliferation and chondrocytes is equal
- As a result, the growth plate is displaced away from the middle of the diaphysis – resulting in bone length

Five Zones of the Epiphyseal Growth Plate

1. Zone of reserve (resting) cartilage
2. Zone of proliferation
3. Zone of hypertrophy
4. Zone of calcification
5. Zone of ossification (Chondrocytes are degenerating, spaces between cartilage is invaded by capillaries and osteoprogenitor cells from the marrow in spaces of diaphysis, Osteoprogenitor cells congregate on the calcified cartilage spicules differentiate into osteoblasts and lay osteoid, New bone matrix become ossified – Osteoprogenitor cells need to sit on the cartilage to lay form osteoblasts to lay osteoid



Growth in Diameter of Long Bones

- Occurs of deposition of new bone beneath the periosteum
- Compact bone forming the shaft of a fully developed long bone is almost entirely the product of subperiosteal intramembranous ossification
- Osteoclasts destroy the inside layer to ensure lightness
- New bone is laid outside deep to the periosteum

Bone Fracture and Repair

1. **Haematoma Formation –** Blood cells from broken vessels form a clot. These cells ultimately die. Fibroblasts outside the clot replicate, form a loose aggregate of cells interspersed with blood vessels, known as granulation tissue (hours, days)
2. **Formation of Fibrocartilaginous Callus** – Periosteal cells closest to the fracture gap develop into chondroblasts which form hyaline cartilage, and periosteal cells further from the fracture develop into osteoblasts which form woven bone. Fibroblasts in granulation tissue also form hyaline cartilage. These two new tissues grow and unite forming fibrocartilaginous callus – the fracture gap is now closed (1 week)
3. **Formation of a Bone Callus** – The hyaline cartilage and woven bone in the callus is replaced by lamellar bone via endochondral ossification and bony substitution, respectively. The bone become mineralised and blood vessels invade associated with osteoblasts. These osteoblasts form trabecular bone and thus a bony callus (weeks to months)
4. **Remodelling Phase** – Trabecular bone is replaced by compact bone. This involves reportion of trabecular bone by osteoclasts, and production of new compact bone by osteoblasts. The callus is now remodelled to closely duplicate the original shape and strength of the bone.