Bone and joint histology

Science, Biology

* It is a specialised connective tissue.

* Osteogenic cells ⇒ osteoblast (makes matrix, active when young, and after fracture) ⇒ osteocyte ⇒ osteoclast (functions in resorption, breakdown of bone matrix) (makes cavities) (from blood monocyte)

Bone Functions

* Framework for support of the skeleton

* Protection: brain, spinal cord, lungs and heart

* Levers for muscles attached to them via tendons

* Reservoir for minerals e. g. calcium, magnesium, phosphates etc.

Bone Matrix

* Components

* Extracellular matrix (ground substance and fibres) consists of inorganic material (65%) e. g. calcium phosphate, calcium carbonate, magnesium, sodium, potassium, bicarbonate, fluoride, citrate, sulfate, and hydroxide.

* Minerals give bone hardness and rigidity

* Organic component (35%) mostly type I collagen (95%)- gives bone slight flexibility; and ground substance e. g. GAGs with proteoglycans, which contain chondroitin and keratin sulfates which give bone resilience

* Development

1. Bone starts as osteoid, which is collagen and GAG’s with no minerals

2. Bone becomes mineralised (immature, primary, or woven bone). It is the first bone to appear in development and in repair after fractures

3. Bone starts to remodel as the adult form (mature, secondary, lamellar)

Bone Cells

1. Osteoprogenitor (osteogenic) cells: from embryonic mesenchyme, which differentiate into osteoblasts. Found in inner cellular layer of the periosteum, lining Haversian canals, in the endosteum (lining medullary cavity)

2. Osteoblasts: derived from osteoprogenitor cells, form and grow new bone by synthesis of organic components of bone matrix. Found on the surfaces of existing bone tissue where they deposit new bone matrix (osteoid) which contains no minerals. Later mineralization occurs, tissue is new bone. Osteoblasts extend processes with neighbouring osteoblasts for molecular transport. Sit on the edge of bone.

3. Osteocytes: flat cells with small cytoplasmic processes. Aid in the maintenance of bone tissue and storage of minerals. Each osteoblast becomes surrounded by secreted matrix, once this occurs, the cell is known as an osteocyte (mature bone cell), and the space it occupies is a lacuna. Radiating out in all directions from the lacuna are tunnel-like spaces (canaliculi) which house the cytoplasmic processes of the osteocytes. The canaliculi allow transfer of nutrients, wastes between the osteocytes and

blood. They are very active cells. Communicate via cytoplasmic processes in the canaliculi, metaboliccommunication.

4. Osteoclasts: large motile, multinucleated cells (150 um diameter) which contain up to 50 nuclei. These cells break up and resorb bone. Osteoclasts occupy shallow depressions (Howship’s lacunae). The ruffled border (infolded plasma membrane) is that part of the cell that is directly involved in the resorption of bone. It removes bone enzymatically, mineral deficiencies then the osteoclasts become active to release the minerals that have been stored in bone, hence the person becomes fracture prone. The multinuclear nature of the osteoclasts is a good identifying factor

Periosteum and Endosteum

* Vascular, fibrous layer surrounds bone except over articular surfaces.

* 2 layers

* Outer layer is collagen with some elastic fibres. This layer distributes vascular and nerve supply to bone.

* Inner layer is cellular (osteogenic layer, osteoprogenitor cells), gives rise to new bone.

* Central cavity of bone is lined with endosteum- thin CT composed of osteoprogenitor cells and osteoblasts.

* From the outer layer of periosteum, fine bundles of collagenous fibres (Sharpey’s) penetrate the underlying bone at intervals to attach the periosteum, especially at the sites of attachment of tendons and ligaments.

* The periosteum contains blood vessels, nerve endings, and ligament and tendon attachments.

Mature bone Organisation

* Dense (compact) at the edge

* This type has Haversian systems (osteons) which is a complex of 4- 20 concentric, bony circular lamellae surrounding a central (Haversian) canal (20- 100 µm diameter)

* The canal contains blood vessels, lymphatics, with a few unmyelinated nerve fibres, loose CT and flattened osteogenic cells and osteoblast cells that line the lumen of the canal

* Osteocytes are in lacunae (in the concentric lamellae) located within or between the lamellae

* A second arrangement of lamellae is found between the osteons (interstitial lamellae- formed by the collapse of old Haversian systems). These are remnants of older, partially resorbed Haversian systems.

* A third arrangement (circumferential lamellae) are rings of bone around the entire bone, beneath the periosteum

* Radiating from the lacunae are tiny channels (canaliculi). Processes of the osteocytes enter these canals and communicate with adjacent osteocytes where an exchange of gases occurs, nutrients are supplied to the cells and metabolic wastes are eliminated.

* The Haversian canals communicate with the marrow cavity, the periosteum and with each other via the transverse Volkmann’s canals, which run at right angles to the long axis of the bone. Each osteon has a cement line of calcified ground substance with some collagen fibres.

* Spongy (Cancelllous Bone):

* This type is not organised into Haversian systems but is a meshwork of thin bars (lamellae) or trabeculae of bone lining the marrow cavity

* The spaces within this latticework are filled with bone marrow. The trabeculae house osteocytes in lacunae that are fed by diffusion from the marrow cavity.

Blood and Nerve Supply

* Bones have periosteal vessels, which penetrate the bone of the diaphysis of long bones and divide into branches that enter the Haversian systems. These vessels supply the osteocytes embedded in the calcified matrix.

* Larger vessels pierce the epiphysis to supply the spongy bone and the midshaft to supply the medullary cavity.

* Small myelinated and unmyelinated nerves go into the Haversian canals.

* The periosteum contains many pain fibres which makes it sensitive to injury e. g. blow to the tibia

Bone Development and Growth

Histogenesis (differentiation)

* Bone development is mesodermal in origin and if the tissue is membrane like (a sheet of mesenchyme or loose CT), it is intramembranous bone formation

* If bone replaces cartilage that is largely resorbed before bone is formed, this is endochondral (intracartilaginous) bone development.

Intramembranous Bone formation

* The process involves mesenchyme to bone directly (osteoblast laying bone)

* Locations: flat bones, e. g. the skull, mandible, clavicle

Endochondral bone formation

* The process in this type of bone formation occurs in 2 steps:

1. A miniature hyaline cartilage model is formed in the region where the bone is to grow within the embryo

2. The cartilage model grows appositionally and interstitially and serves as a structural scaffold for bone development. It is then resorbed and replaced by bone (all the cartilage is replaced by bone)

* Locations: long, short bones, pelvis and vertebrae

Developing bone region at epiphyseal plate

* Area between shaft and epiphysis is the epiphyseal plate.

* Proliferation occurs at the epiphyseal aspect and replacement by bone takes place at the diaphyseal side of the plate

* Growth at both ends of the bone is hormone regulated

* There are a series of 5 zones beginning at the centre of the disc and go towards the diaphysis:

1. Zone of reserve cartilage (resting zone) : chondrocytes through the matrix are mitotically active producing hyaline cartilage

2. Zone of proliferation: chondrocytes proliferate and form stacks of cells that parallel the direction of bone growth. (Cartilage dies- lose blood cells- hence the bone invades the space)

3. Zone of maturation and hypertrophy (Expanding): chondrocytes mature, hypertrophy and accumulate glycogen in their cytoplasm. No mitosis occurs

4. Zone of calcification and cell death: Chondrocytes die and the cartilage matrix becomes calcified impregnated with calcium and phosphorus

5. Zone of ossification: blood vessels invade spaces left by the dying chondrocytes carrying osteoprogenitor cells from the periosteum and differentiate into osteoblasts which elaborate matrix that becomes calcified

on the surface of calcified cartilage. As the matrix calcifies, some osteoblasts are entrapped as osteocytes and bone trabeculae are formed. Coalescence of trabeculae creates spongy bone. Resorption of spongy bone by osteoclasts in the centre of the diaphysis enlarges the medullary cavity.

Summary of histochemical processes for both models of bone formation

* Osteoblasts secrete osteoid with no minerals

* Formation of primary bone whereby osteoid is mineralized

* Formation of secondary bone as compact or spongy bone

Growth in length of long bone

* Due to interstitial growth of epiphyseal cartilage

* Growth continues until around 20 when the epiphyseal plate closes (cartilage is replaced by bone) and growth in length stops

Growth in width of long bone

* As a result of appositional growth from the surface and resorption by osteoclasts of the inner shaft so that the marrow space can be enlarged

Bone Remodelling

* Continual remodelling occurs in response to forces (e. g. teeth growing jawbones). Bone is deposited due to traction and resorbed due to pressure.

* In young, bone deposition exceeds bone resorption. In the adult bone deposition is balanced with resorption.

Joints

* Joints are classified according to the degree of movement between the bones of the joint:

* Synarthroses: little or no movement. There are 3 types based on the tissue making up the union:

* Syndesmosis is the union of bones by dense CT e. g tibiofibular and radioulnar joints

* Synchondrosis is a junction by cartilage e. g. IVDs and symphysis pubis

* Synostosis is a joint united by bone e. g. skull sutures (Starts off as fontanelles)

* Diarthroidal (synovial) e. g. knee, hip, shoulder have great freedom of movement and have a CT capsule around a joint cavity held by ligaments.

* The joint has an articular cartilage (hyaline) with no perichondrium. The capsule is lined (except over the articular surfaces) with a cellular, vascular, folded synovial membrane made of loose CT which secretes a viscous lubricating, synovial fluid. The viscosity of the fluid varies with temperature.

*Fibrous- collagen- little to no movement- interosseous ligament

*Gomphosis- tooth joined by cartilage