Bone and cartilage – Klára Dolinová, Yoni Solomonov

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Bone and cartilage are supportive tissues having various functions. Their types and classification are depicted below.

Bone tissue

Unlike one might think, bone tissue is a live tissue having variety of metabolic and structural functions.

Function of bone tissue

1. Structural support – provides strong and flexible skeleton, a structural component of the body. Allows attachment of muscles and movement.
2. Protective functions of internal organs.
3. Storage site of calcium and phosphates.
4. Houses bone marrow in the medullary cavity.

Classification and structure

Histological classification follows architecture of collagen I fibers in bone matrix.

In **primary bone** (woven, fibrillar), collagen fibers are not organized and are dispersed rather randomly. It is a typical stage in bone development of a growing fetus or in newly formed bone at the growth plate in growing child. The woven bone that is newly formed is replaced by a lamellar bone.

Secondary bone replaces primary bone and its collagen fibers arrange into thin layers - lamellae. These lamellae can form Haversian systems or plates that follow vectors of biomechanical forces applied on skeleton. Secondary bone is constantly remodeled.

Secondary bone tissue can be thought of as spongy bone or compact bone. Quick remainder on anatomical structure of a long bone – at the end's **epiphysis**, at the middle - **diaphysis**.

Spongy – due to its appearance, trabecular network of cavities - allow housing of the bone marrow. Spongy bone usually found in the epiphysis of long bones, in the core of short bones and in the middle layer of flat bones (in the skull it is termed "diploe").

Compact – usually at the surface of the bone – tightly arranged at **lamellae** (plates) with compressed **osteocytes** between layers (details of structure below).

Histological features of woven bone:

- Cells are randomly dispersed in the ECM.
- Collagen fibers are oriented randomly in all directions.
- Lower content of inorganic compounds that in fibrillary bone

Histological features of woven bone:

Lamellar bone – (or secondary bone) typically arranged in a circular **osteon** structures (=**Haversian system**). Circularly arranged in regular manner, layers of calcified ground substance with collagen fibers (i.e. extracellular matrix) and cell – osteocytes in between these layers. This type of bone is the adult form of compact bone.

For orientation purposes lets imagine a long bone as a tube. The surface of the diaphysis is the external surface of the compact, lamellar bone. And the cavity inside the tube is the medullary cavity that houses the bone marrow (where blood cells are formed). The outer surface of the bone is lined by **periosteum** and the inner surface is lined by **endosteum**.

Outer surface of the bone – periosteum lines it – dens irregular connective tissue having the cells: 1) osteoblast, 2) osteoclast. The periosteum is attached firmly to the bone surface by strong fibers – Sharpey's fibers.

The endosteum lining the inner surface of the bone is made of thin layer of loos collagen connective tissue housing osteoprogenitor cells and osteoblasts. One of the important function of the endosteum is bone repair, this is made to large extent by the osteoprogenitor cells.

Cells of bone tissue

Osteoblast – "bone building cell" – they are present on the surfaces (inner and outer) of the bones. Highly active cells that synthesize bone matrix, as they produce it, they become surrounded by their own product. This is the part of bone remodeling process. Those cells activity can be regulated according to body needs.

Typical features of this cell are - highly developed RER & Golgi (collagen synthesis), euchromatic nucleus (transcription), typically arranged in one layer. The cell cytoplasm has roughly cuboidal shape and extensive cytoplasmic extensions. The organic bone matrix is called **osteoid.** They are always on the bone surface.

Osteocytes – less active form of osteoblast, has less cytoplasmic extensions and the synthetic activity is reduced. Those cells are positioned in tiny spaces between lamellae called lacuna. They are surrounded by bone matrix.

Osteoclast - "bone destroying cells" those cells are aimed to resorb the cell and therefore their description as "destroying", the process of bone resorption is a highly regulated process. Typical morphological features of those cells: localized on the bone surface in specific places – **resorption bays**. Osteoclasts are multinucleated – formed by fusion of few cells. Cell surface oriented towards bone is modified to form a tightly sealed ruffled border.

Together with the action of osteoblast, those cell continuously resorb and synthesize bone matrix – bone remodeling.

Osteon – Haversian system

Typical arrangement of the bone matrix in compact bone is in circularly lamellae - Layers of calcified matrix with osteocytes and lacunae in between the layers. 4 – 20 layers makes an osteon. In the center of each osteon there is haversian canal housing vessels and nerves

supplying the bone tissue. Volkmann's canals are horizontally running canals aimed for communication between haversian systems (see presentation for detailed scheme).

Ossification

Formation of bone is called ossification, there are two main types of bone formation – endochondral (indirect) and intramembranous ossification (direct).

Intramembranous: typical type of ossification for flat bones such as bones of the calvaria (skull vault). In this type of ossification there is formation of bone producing cells **directly** from mesenchymal cells (embryonic connective tissue cells) without a cartilage model.

Basic steps: mesenchymal tissue condense→ mesenchymal cells differentiate into osteoprogenitor cells → differentiation into osteoblast – osteoid synthesis → ossification centers appear in the condensed mesenchyme → ossification centers fuse.

Endochondral ossification: mostly seen in the formation of long bones. In this type of bone formation mesenchymal cells make a hyaline cartilage model and this in turn ossify into a bone tissue. During child's growing phase of life, the long bone consists of growth plate (= growth cartilage = epiphysial plate) at the junction of diaphysis and epiphysis. At this place the cartilage grows and the ossify continuously and thus the bone is elongated. The epiphysial plate ossify completely at 18 – 25 years.

When observing the growing cartilage under a microscope one may identify several zones:

1. Resting cartilage zone - hyaline cartilage.
2. Zone of intensive mitosis – proliferating zone of chondroblasts. Chondroblasts form columnar isogenous groups.
3. Zone of hypertrophy – chondroblasts grow in **size** (not in number of cells). While growing they compress the matrix in between the cells.
4. Zone of calcification – matrix is calcified, chondroblasts undergo apoptosis and are removed by osteoclast activity. Only fibers of mineralized matrix are left behind.
5. Zone of ossification – osteoblast differentiate from the periosteum, (previously perichondrium) and start osteoid production along mineralized matrix. Marrow cavities are formed in the places of former chondroblasts.

Keep in mind that the formed bone is now woven bone – primary. It will be eventually replaced by definitive secondary bone.

Cartilage

Cartilage is a type of supportive connective tissue. It has a function in shock absorbance, reducing friction in joints, and provide structure of internal organs. Cartilage tissue is flexible and rich in ECM with abundant amorphous ground substance. Generally said it is abundant in collagen type II, and there are also some elastic fibers (content vary with type of cartilage). This type of tissue is avascular and not innervated, thus this properties are provided by some supportive structures (depicted below).

Cells of cartilage are **chondroblast** and **chondrocytes**. Typical features: those cells have high synthetic activity and therefore – euchromatic nucleus, well developed RER and Golgi. They are

functioning in production of the type II collagen and elastin. Differentiation starts from the **perichondrium** as **perichondral fibroblast** and progressively change shape from flat cells (chondroblast) to more rounded shape (chondrocytes) as they move towards the core of the cartilage. The extracellular matrix is rich in hyaluronic acid. As chondroblast → chondrocytes are in the core of the cartilage, they divide and make a isogenous group in a common space – lacuna.

Perichondrium – it is a supportive layer that surrounds the cartilage and supports it nutrition. The perichondrium is highly innervated and vascularized. It has two main layers – outer **fibrous** layer and inner **chondrogenic** layer.

Another way of nutrition of cartilage is by **synovium** – a fluid produced by the cells of the synovial membrane of the joint capsule and secreted to the joint cavity.

Cartilage classification

Three main types of cartilage are distinguished according to their function, mechanical properties and morphology.

Hyaline cartilage

Flexible and strong type of cartilage specialized in sustaining mechanical impact and providing structure. Found in joint surfaces of bones, growth plate of long bones, larynx, trachea and parts of the bronchial tree, can be seen in skeleton model of a fetus and in the rib cartilages.

Special feature of hyaline cartilage is that it is supported by perichondrium (except for joints where it is supported by synovium). The chondroblast are arranged in isogenous groups – those are groups of few cells in a common lacuna inside the matrix of the cartilage. This is darker appearing matrix that surrounds the isogenous groups is called territorial matrix (**basophilic).** The basophilic appearance is due to a high content of acidic GAGs.

Elastic cartilage

Consists of elastic fibers, and collagen II. Special features it the high flexibility, **rare or absent isogenous groups.** Nutrition by **perichondrium**.

Can be found in - epiglottis, cuneiform and corniculate cartilages (of larynx), auricle and external acoustic meatus and in the eustachian tube.

Fibrous cartilage

This type of cartilage is less flexible, it is stiffer, and it is positioned in places where mechanic resistant is needed. Special features are – high content of collagen type I, **No isogenous groups**, **No perichondrium**. Found in - intervertebral disc (anulus fibrosus), pubic symphysis and in menisci of the knee joint.