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ANIMAL BONE – A BRIEF INTRODUCTION

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Abstract: The paper gives a brief introduction to animal bone. A calcification of animal bone is presented based on shape, structure and development. The structure of bone is described. The process of ossification is explained. Physical and chemical aspects of bone are presented.
Keywords: Animal bone, classification, structure, ossification.

1. INTRODUCTION

The main supporting structure of the vertebrate body is the skeleton of bony tissue. It consists of bones and cartilages. The muscles, tendons and ligaments are also attached to bones and cartilages. The skeleton provides rigidity for the body. It forms a number of mechanical levers with attached tissues for the free muscular action as well as for the movement of a part or the whole body.

Bones give shape and support to the body and resist all forms of mechanical stresses. They provide surface for the attachment of muscles, tendons and ligaments.

Soft organs such as lungs, heart, spinal cord and brain are protected from injury by thoracic cage, vertebrae and skull respectively. Moreover, thorax and rib cage movements are important in external respiration. White blood cells and lymphocytes are made in the red bone marrow. Bone serves as an important reservoir for calcium, which can be drawn upon when required for special metabolic activities. 97% of the total calcium in body accumulates in the skeleton. It is important to recognize the living and plastic nature of the bone. It is highly vascular, with constant turnover of its calcium content. It shows a characteristic pattern of growth. It is subjected to disease and heals after a fracture. It has greater regenerative power than any other tissue of the body, except blood. It can mould itself according to changes in the stress and strain it bears.

The tubular character of long bones in the body makes for lightness and economy of material. At the same time it provides accommodation for the bone marrow. Some of the bones in the skull are excavated by extensive air sinuses. The body of the upper jaw (maxilla)

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is a hollow shell with relatively thin walls, which make the skull light in weight, help in resonance of voice, and act as air-conditioning chambers for the inspired air. There are certain bony modules found in the body, whose possible functions are to resist pressure, to minimize friction, to alter the direction of pull of the muscle and to maintain the local circulation.

A study of stresses and strains to which skeletal elements are exposed in normal or abnormal activities during life is a considerable interest for the understanding of the characteristic architecture of individual bones. It is also of practical importance in studying the factors responsible for different types of fracture. The importance of bones in anthropology, forensic medicine and orthopedic hardly needs any introduction.

1.1 . CLASSIFICATION OF ANIMAL BONES

Animal bones are classified according to various factors. Shape, structure and development of the bones are some of the important factors to be considered for the classification.

1.1.1. Classification on the basis of shape

According to shape, bones are classified as long bones, short bones, flat bones, irregular bones, pneumatic bones, seasamoid bones and accessory bones.

Long bones

Each long bone has an elongated shaft and two expanded ends, which are smooth and articular. The shaft typically has three surfaces separated by three borders, a central medullary cavity and a nutrient foramen directed away from the growing end. The examples of long bones are humerous, radius, ulna, femur, tibia and fibula.

Short bones

The shape of the short bones is usually cuboid cuneiform, trapezoid or scaphoid. The examples are carpal and tarsal bones.

Flat bones

They resemble shallow plates and form boundaries of certain body cavities. The examples are bones in the vault of the skull, ribs, sternum and scapula.

Irregular bones

A number of irregular bones exist in the animal skeleton. They are vertebra, hipbone and bones in the base of the skull.

Pneumatic bones

Certain irregular bones contain large air spaces lined by epithelium. The examples are maxilla, sphenoid, ethmoid, etc.

Sesamoid bones

They are the bony nodules found embedded in the tendons or joint capsules. Patella, pisiform, fabella, etc are the examples of sesamoid bones.

Accessory bones

These bones are not always present. They are often bilateral and have smooth surfaces without any callus. Examples are satural bones, ostrigonum etc.

1.1.2. Classification on the basis of structure

Structural classification of the bone is done either microscopically or macroscopically. Macroscopically the architecture of the bone may be compact or cancellous. Microscopically the bone is of four types viz., Lamellar, fibrous, dentine and cement.

Compact bone

Compact or cortical bone is dense in texture like ivory. It is made up of a number of cylindrical units called Haversian system. Each Haversian system is constituted in four parts, Haversian canal, concentric bony lamellae, lacunae and canaliculi. This type of bone is an adaptation to bending and twisting forces.

Cancellous bone

Cancellous, Spongy or trabecular bone is open in texture. It is made up of a meshwork of rods and plates between which are the spaces containing marrow. A network of rods produces open cells while one of the plates gives closed cells. Cancellous bone is an adaptation to compressive forces.

Lamellar bone

Most of the bones, whether compact or cancellous, consist of thin plates of body tissue called lamellae. In compact bone, lamellae are arranged in concentric cylinders while in cancellous bone they are arranged in piles.

Fibrous bone

Fibrous bone consists of parallel bondles of dense collagenous fibers. It is found in young foetal bone. It is common in reptiles and amphibia.

Dentine

The hard material present in teeth is called dentine. It is a tissue even denser than the bone. It is hardest, densest and most enduring part of the vertebrate body.

Cement

It is a bone like substance. It anchors the tooth firmly to the Jaw and occurs outside the dentine around the roots of the tooth.

1.1.3. Classifications on the basis of development

Bones are classified on the basis of development as membrane bones, cartilaginous bones and membrane – cartilaginous bones.

Membrane bones

Membrane or dermal bones are formed in membrane. They are derived from meseuchymal condensations. For example of these are bones of the vault of skull and facial bones.

Cartilaginous bones

Cartilaginous bones form in cartilage. Bones of limbs, vertebral column and thoracic cage are the examples of this class.

Membrano – cartilaginous bones

This class of bones is developed partly in membrane and partly in cartilage. Examples of these bones are clavicle manclible, occipital, temoral, sphenoid, etc.

1.2. STRUCTURE OF ANIMAL BONE

As it is already discussed in the structural classification that bone occurs in two forms, compact bone and cancellous bone. The most obvious difference between these two types of bones is in their relative densities or volume fractions of solids. Bone with volume fractions of solids less than 70% is classified as cancellous, that over 70% is compact. Most of the bones in the animal body have both types, the dense compact bone forming an outer shell surrounding a core spongy cancellous bone. In this configuration the bone forms a sandwich structure similar to man made sandwich structures of fiber glass faces separated by a foam core. Like a man made sandwich structure, the mechanical behaviour of the bone sandwich depends on the properties of the components and their geometry.

A section of typical compact bones, the lamellae, which are disposed in flat layers immediately beneath the prelostal tissues. In the substance of the shaft, they are arranged in concentric rings round the fine canals which penetrate the bone every where, usually in the longitudinal direction. These are the Haversian canals. They range from 20 to 100 μm in diameter and each contains minute blood vessels accompanied by fine nerve fibers and losely enmeshed in reticular tissue. The canals branch and anastomose with each other to some extent, and provide essential channels for carrying blood into the bone substance. Each canal and its series of encircling lamellae comprise what is called Haversian system. In the angular spaces between adjacent concentric systems the lamellae are disposed more irregularly which are termed as interstial lamellae. Some important bones of skeletal system are as follows.

Ribs : Curved elastic rods which form the greater part of the skeleton of the thorax.

Scapula: The shoulder blade which is flat triangular bone lying beneath the superficial muscles on the lateral aspect of the thorax at its cranial end.

Femur : The bone of the thigh.

Humerous : The bone of the arm from shoulder to the elbow.

Radius : It is the shorter of the two bones of the fore arm.

Ulna : It is the longest bone of the fore arm.

Tibia : It is situated at the medial side of the leg.

Fibula : It is located on the lateral side of the leg.

Skull : It is a bony case articulating with the cranial end of the vertebral column.

Thoracic vertebrae

The attachment acts as a shock absorber to dissipate the upthrust received by the fore limbs as the animal strike the ground.

1.3. OSSIFICATION OF BONE

The process of bone formation is called ossification. Some bones develop directly from the mesodermal mode. Conversion of the mesodermal model into bone is called intramembranous ossification and the bones called membrane bones. Facial bones and bones of the vault of skull are the membrane bones. However, in most of the bones, the mesodermal stage passes through a cartilaginous stage. Conversion of cartilaginous model into bone is called intracartilaginous or endochondral ossification and such bones are called cartilage bones. The bones of limbs, trunk and base of the skull are cartilage bones.

Ossification takes place by the centers of ossification, each one of which is a point where bone formation begins. Microscopically, an ossification center is a point of excessive vascularity proliferating mesenchynel cells and the bundles of collagen fibres laid down by them. The centers of ossification are of two types, primary and secondary. Primary centers of ossification appear before birth. The secondary center appears after birth with a few exceptions. Many secondary centers appear during puberty.

1.4. CHEMISTRY OF BONE

Bone consists of 45% water, 30% protein, 15% bone salts and 10% lipids. The bony matrix forming the bony lamellae is partly organic and partly inorganic. Organic matrix forms 30 to 40% of the bone weight. It is made up of fibres of collagen proteins embedded in a mucopolysachaside protein complex. The organic matrix is known as osteoid matrix. The cells of bone are called osteocytes. They are found in spaces or lacunae. Each cell has strands of its protoplasm connecting with other bone cells by fine channels. These link up with central haversian canals providing essential food and oxygen.

The inorganic matrix forms 60 to 70% of the bone weight. The crystals of inorganic matrix are tiny, about 20 nm long. The inorganic matrix is made up of calcium phosphate (85%), calcium carbonate (10%) and traces of calcium fluoride, magnesium chloride, etc. The approximate composition of calcium phosphate has a formula

$$3\ Ca_3\ (PO_4)_2\ \ Ca\ (OH)_2$$

the important ions of the bone salts are calcium, magnesium, phosphate, carbonate, hydroxyl, chloride, fluride and citrate. It is worth to mention that bones store 97% of the body calcium and a very large amount of body phosphorous.

Calcium and Phosphate are as important as sodium and potassium in the regulation of basic body functions. Inorganic calcium and phosphate are not related closely with respect to most of their essential roles in vertebrates physiology, but these are inseparable with respect to their involvement in the structure of bone and teeth. Calcium phosphate incorporated into bone matrix serves as the major reservoir for those ions. Consequently a discussion of the endocrine regulation of calcium homeostasis cannot be divorced entirely from the regulation of phosphate.

1.5. PHYSICS OF BONE

Bone is a hard and rigid tissue with low density. The inorganic crystals make bone considerably stiff Collagen, the organic part of the bone is a soft tissue. The young’s modulus of collagen is about 1 GNm^{-2}, while that of bone is about 10 to 20 GNm^{-2}. Inspite of this, collagen also contributes to the strength of bone. In fact, bone seems generally to the rather stronger than collagen. It seems odd that such tiny oystals can strengthen bone. But a similar effect can be seen in the filled rubbers which are used for making tyres. They consist of rubber mixed with fine root. The root, not only stiffens the rubber, but also makes it very much stronger.

Bones have low density because of its structure. Outer parts of the bone will be compact, while the inner layers will be of spongy bones. Moreover, the strength of hollow long bones will be greater than a solid rod of equal length and weight.

In virtue of bones inorganic frame work of calcareous material it has lent itself more readily than other tissues to the study of mechanical adaptation in the body. Close study has revealed that in its internal structure, a bone is adapted in a very remarkable way to resist the stresses to which it is subjected during life.

Bone is required to have strength of two kinds. One to resist compression or crushing forces, and other to resist tensile or disrupting forces. The tensile and compression strengths of bone are an equivalent order and here in bone show considerable advantage over many constructional materials, such as iron and wood. They are strong in one direction but weak in the other. An engineer may require to use two different kinds of material to resist tensile and compression forces. Bone is almost equally adapted for both purposes. The tensile strength of bone has been demonstrated by experimental studies on femur of rats. It showed that the average breaking stress to bend, to be found 35000 lb/in^2 as compared with 40,000 for cast iron. On the other hand, bone is about three times lighter than cast iron and very much more flexible. It was also found that bone material is more than three times as strong as timber and half as strong as mild steel.

An interesting observation was made that when the axial load on the femur is increased five times by jumping from a height, the strength of the bone is 140 times greater than is necessary for such an action. With this, the conclusion arrived is that bones are made to withstand the severe actions of bending and twisting. A mechanical analysis of the human femur as a structural element of a machine had given similar results. According to the analysis, the load on the head of the femur in a standing position is 0.3 of the body weight. In running, the dynamic effect of the sudden application of the body weight produces stresses which are 1.6 times more than the body weight.

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