Structural and Functional Anatomy

for Students and Teachers of Physical Education

Third Edition

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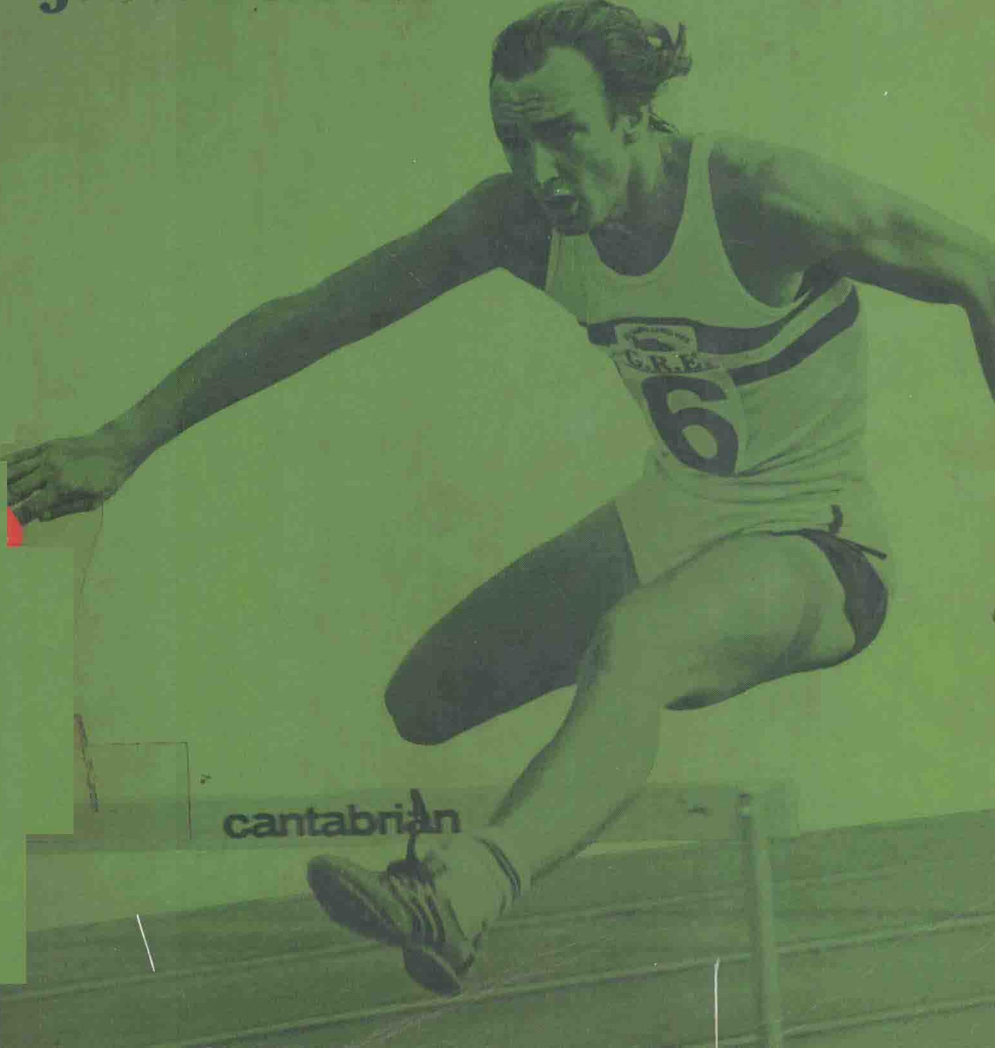

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Structural and Functional Anatomy for Students and Teachers of Physical Education

Third Edition

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Preface to Third Edition

In the previous edition of this textbook it was emphasised that anatomy must be interlocked irrevocably with physiology : structure and function of tissues have now become the same subjects for practical purposes. The broadening of curricula in the biological sciences has now conveniently thrust a new term upon us—**Human Biology**. To meet the changing requirements of students of physical education this book has been re-named and its third edition named *Structural and Functional Anatomy for Students and Teachers of Physical Education.*

Physical education is now dealing in more detail with anatomical and biochemical function than ever before. Because of these changes this edition has had numerous additional inclusions. **The chemistry and physics of muscular work** have been added to the chapter on Work and Movement. Indeed, ramifications of these subjects such as cramp, stiffness, and heat regulation have their due attention. Obesity is also the concern of the physical educationalist, and the balance of caloric intake and output have been considered.

There have been requests for a chapter on muscle injuries. Accordingly, an additional chapter has been devoted to the pathology, causes, frequency and treatment of the various types of rupture of muscles.

The excretion of waste products, the osmotic pressure of blood, and the regulation of the quantity and acidity of body fluids deserve as much attention as does the metabolism of food. Thus the physical educationalist is provided with an additional chapter on The Kidneys and the Formation and Evacuation of Urine. The influence of physical exercise on this aspect of functional anatomy is stressed.

Over-all, the increasing demands of the physical education curriculum have been approached from a functional aspect in this new edition.

Sydney. 1977. J. W. P.

Acknowledgements

First and foremost the author is indebted to the late Professor John Short of the Department of Anatomy at King's College, Newcastle upon Tyne, for his many suggestions and general enthusiasm in the preparation of this book. His advice has always been of the greatest value.

To many authors I am much indebted for the loan of illustrations and acknowledgement is made under each figure. To my fellow anatomists, Professor Lockhart of Aberdeen University and Professors Smout and McDowall of Birmingham and London Universities, I must express particular gratitude for their photographs and drawings which have helped me so much in compiling this work.

Mr. C. K. Warrick of the Department of Radiology, Royal Victoria Infirmary, Newcastle upon Tyne, has kindly supplied the X-ray films of bones and joints.

Four of the author's students, Messrs. J. M. Guppy, W. G. D. Morgan, R. Thursby and M. P. Dunlevy from the Medical and Dental Schools at Newcastle upon Tyne, kindly agreed to pose for photographs reproduced in Figs. 152, 156, 157 and 161 (*a*) and (*b*). Their posture and muscularity has been put to good use!

In the subsequent editions, Dr. Cedric Thwaites has given valuable assistance in the pruning and weeding found necessary in every book. The artistic skill of Mr. Peter Mills of the Department of Anatomy at the University of Sydney has enhanced the clarity of many illustrations. Many teachers of physical education have also given the author their valuable advice concerning the requirements of the changing curriculum in the now highly specialised profession of physical education.

Contents

Chapter 1

The Role of Anatomy in Physical Education

No military commander would attempt to fight a battle without a previous knowledge of the terrain over which his troops will move. The exact position, depth and rate of flow of rivers, the contours of the land, the location of forests, roads, railways and towns are for his detailed study. Even the nature of the soil and the weather forecasts are essentials for military operations. How futile then to attempt any operation, whether surgical, manipulative, diagnostic or educational, on the human body without an adequate knowledge of its geography and landmarks. Lest it be argued that anatomy is but a science of foreign names, it must be pointed out that names of muscles, arteries and bones matter little to the physical educationalist, but it is their *functions* and *positions* that are the be-all and end-all of movement and nutrition. With Juliet we may say

> " What's in a name ! that which we call a rose
> By any other name would smell as sweet."

Students who are being trained to care for the proportional development and natural growth of the child and adolescent must have a background of scientific training. This training must include a knowledge of muscle action both from mechanical and nervous points of view. Such a trainee must understand the structure and nutrition of the organs and parts with which he is dealing. He must know the rate of development and respective alterations in size and strength of muscles, joints, ligaments and bones. He must understand the mechanism of circulation and respiration and some of the metabolic processes associated therewith. Finally, he must possess an elementary psychological acumen in order to understand the attitude of children and adolescents to physical education. As in all teachers the development of a pleasing personality is commensurate with a pleasant form of instruction, although this is beyond the scope of this book. These outstanding features in the training of a Physical Educationalist distinguish him from a Physical Training Instructor. In short, the student and teacher of physical education is essentially a *scientist*.

To be able to prescribe exercise for the growth and maturation of the human body it is necessary to understand the relationship between bone, ligament and muscle and their important role in the cultivation and maintenance of correct body balance. There must be an ability in the teacher to analyse movements and to determine which muscles are working, how they are working and how much effort is being expended. At the same time there must be an understanding of how much effort is required for certain groups of muscles in specified positions and whether or not that effort is an economical one. An athletic coach knows that the greatest results emanate from the maximum economy and indeed the hall-mark of the great athlete is the apparent minimum expenditure of effort as a result of that economy.

These problems must be dealt with anatomically, physiologically and psychologically ; and whether the physical educationalist is dealing with the athlete or the young child he must be aware of the body mechanics involving posture, balance and group movement.

The student of anatomy learns that the internal structure of bone and muscle shows a very definite pattern and that individual muscles such as the adductor magnus, gluteus maximus and gastrocnemius are made up of several sections which have respective attachments and therefore respective actions. The student of physiology knows that muscle possesses properties of contractility and elasticity and that muscle is always being stimulated to produce a certain degree of tonus. But neither of these students relates these facts to the problems of *posture* and alteration in postural habits. Neither do they learn to appreciate from their specialised knowledge the effectiveness of motor performance. It is, therefore, left to the students and teachers of *physical education to use anatomy and physiology as sciences which will assist them in the observation of motor performances as a means towards the development of the whole individual.* This method of development is seldom employed in other branches of education ; and the analysis and investigations of human movements play a unique part in physical education. This science is called ***kinesiology*** and it is dependent upon the application of physiology, histology and physics as well as anatomy.

It is useless for the physical educationalist merely to learn that the deltoid muscle, arising from the anterior border of the lateral one-third of the clavicle and from the acromion and spine of the scapula to gain insertion into the lateral side of the humeral shaft, must act as an abductor of the shoulder joint. It is useless because by these facts alone he has not appreciated the complexities of the simple movement of raising the arm above the head—the variations in actions of a single muscle, and of the other muscles involved (supraspinatus, serratus anterior, rhomboids, trapezius) with bone movement. In other words muscular analysis and evolution of respective muscle work has been ignored, and the result might well be the development of certain muscles and the neglect of others. In this case, the " winging " of the scapula (so common in adolescents) from the weak serratus anterior has been overlooked and the " development of the whole individual " has not been considered.

It is worse than useless for the student of physical education to learn that the diaphragm is merely attached to the lower costal cartilages, xiphisternum and lumbar vertebrae without appreciating its action on the ribs and *how* its movements increase the capacity of the thoracic cage. Such a student has not correlated the combined actions of intercostals, diaphragm and abdominal muscles and therefore has not understood the mechanism of respiration and its variations in chest sizes and shapes. But worse, he has learnt a small fraction of anatomical fact, which to him should be merely academic, and which always tends to bestow a false confidence in an essentially practical scientist.

These are merely two examples of the misapplication of anatomy for the physical education student.

How can the physical educationalist attempt to prescribe the simplest of exercises if he does not understand the meanings of good posture, and *tonus* of muscle? Their interdependence and their intimate correlation must surely be the first step in the understanding of the requirements of (*a*) the child, (*b*) the adolescent and (*c*) the training of an adult athlete. Or again, how can the body be developed and trained when the fundamental well-balanced poise and state of equilibrium between the big muscle groups are at fault? Indeed the student of physical education must realise that the maximum degree of efficiency of any movement can only be obtained by the proper co-ordination of all the muscle groups acting upon the joints.

While this book is not intended to load the memory with numerous histological facts, it would serve a useful purpose by making the student acquainted with the structure of tissues such as muscle, bone, cartilage, skin, nerves, fascia and blood vessels. He will then be able to appreciate the respective functions of these tissues. So intimately is the composition of the tissues knit with their functions that the two subjects of histology and kinesiology are inseparable. Together they form part of the ever-expanding science of anatomy and together they must be studied by the competent physiotherapist, gymnast, physical trainer, as well as by the student of physical education.

One example may be cited to illustrate this connecting link between structure and function. A class of young boys was being instructed by an untrained teacher. Each morning deep breathing exercises would be performed without any movement of the upper limbs. On the contrary the class was instructed to inhale and exhale keeping their arms and shoulders quite still so that " the chest would move by itself ". This instruction showed a lack of knowledge of the elementary mechanics of deep respiration dependent upon the elasticity of the costal cartilages and the resilience of the spongy bone of the ribs. Worse still, the chest walls of these growing boys was being made to do extra work by one instruction (deep breathing) and the brake was being put on by the other (" keep the arms and shoulders still "), for the raising of the arms would have assisted the excursion of the ribs by muscles attached to both the chest wall and the limb girdle.

The action of the heart in its reception and transmission of blood is largely dependent upon the peculiar branching and anastomosing of its muscle fibres (a syncytium) thus facilitating the onward transmission of the impulse to all parts of the heart. Here is another example of the function of a tissue related to its structure. Indeed if the science of anatomy was to be carefully analysed it would be found to consist " of the organisation of cells into tissues, of tissues into organs and of organs into systems " (le Gros Clarke), all of which are so placed so that they can conveniently meet the requirements of the living individual. Anatomy, then, is not merely the geography of the body, but rather the geology, morphology and organisation of the tissues and structures of which that body is composed.

Bearing these salient features in mind, as the student learns about the human body he will realise that each part should be used to its greatest mechanical advantage. *Upon this foundation the whole principle and practice of physical education must ultimately depend.*

Chapter 2
Structure of the Tissues

In considering the structure of the tissues of the human body it is important to realise that all cells originate from one fertilised cell. This divided rapidly into many cells which became modified in size and shape so that they could fulfil their respective functions in their particular parts of the body. In some of the developing tissues the cellular structure to a large extent has been lost and they have become a homogeneous ground substance or *matrix* whose function it is to bind the few remaining cells together. Such tissue is called ***connective tissue*** for its function is to connect together more actively functioning tissues such as cartilage, bone and muscle. It is therefore a scaffolding which holds together and strengthens mechanically the more mobile tissues with more cells. As this connective tissue developed and the neighbouring muscles became more active the matrix developed at the expense of the cells, so that the cellular part became less and the ground substance became stronger, being reinforced by fibres. Thus we find that structures such as muscles, blood vessels, skin and glands are ensheathed and embedded amongst a firm scaffolding of tissue in which few cells are present but in which matrix, either with or without fibrous bands, predominates.

Each of the connective tissues will be studied separately to correlate its function with its microscopical structure.

1. Fat

Fat is known as *adipose tissue* and is found in almost all parts of the body, but there are certain depots or storage regions where the excess absorption of fat or carbohydrate in the diet accumulates. These depots include the buttocks, the breasts, the abdominal wall, the bone marrow, in the neck and around the kidneys. From these depots the fat can be utilised as an additional source of energy in prolonged exercise.

Adipose tissue consists of many densely packed large round cells filled with an oily material enclosed in a very delicate membrane acting as an envelope. These cells can easily be compressed and they are held together by a scanty fibrous matrix in which run a few blood vessels. An ill-defined nucleus may be seen compressed towards the perimeter of the cell. The compressibility of the fat cell and scanty fibrous matrix allows fat to act as a cushion over certain pressure points of the body, while its presence underneath the skin acts as an insulator against loss of heat. The deposit of fat during winter in hibernating animals is well known.

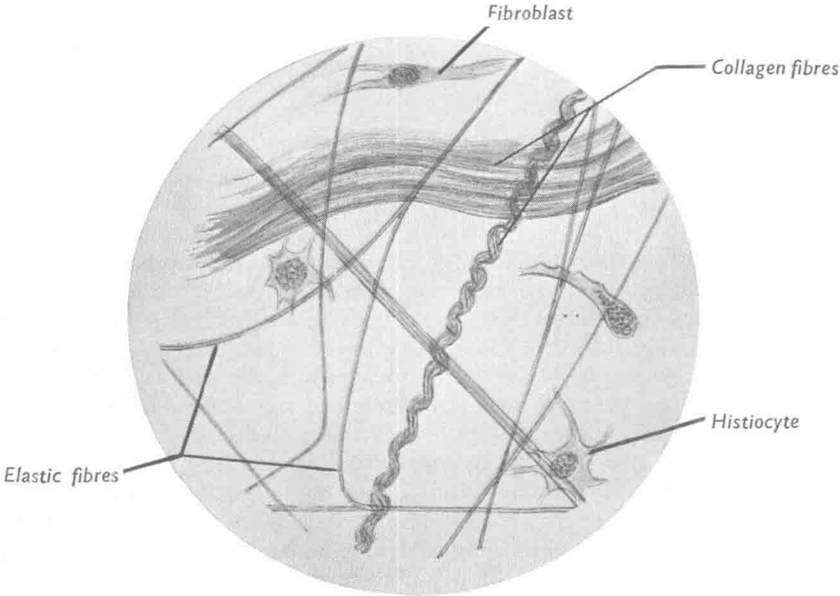

FIG. 1.—Connective tissue

FIG. 2.—Adipose tissue

2. Areolar tissue

Areolar tissue is the most widely distributed of the connective tissues. It extends from beneath the skin to the deep muscles helping to bind them together and, being elastic, it allows their movement so that their actions are enhanced. The elasticity of areolar tissue also permits the expansile pulsation of arteries which it ensheaths, while around abdominal organs it assists in retaining them in position against the weight of their contents and gravity.

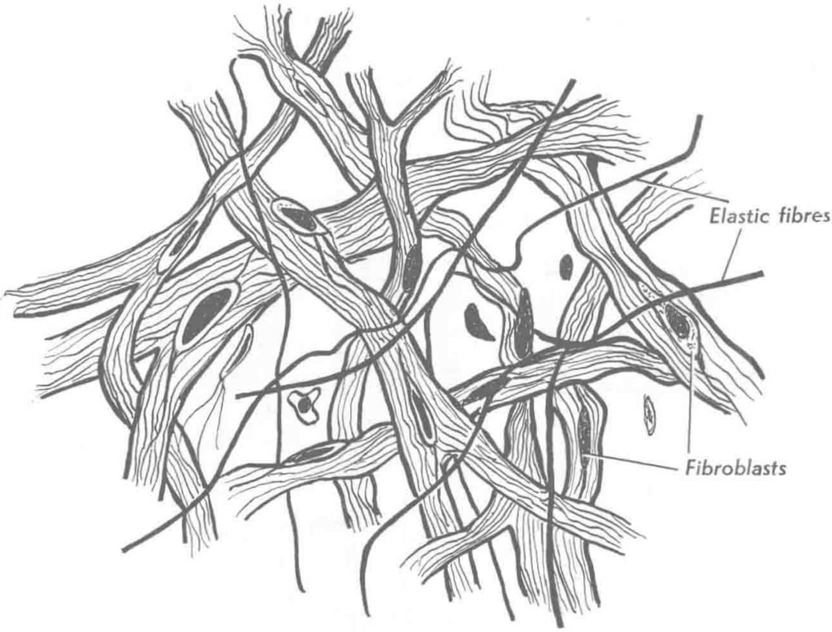

FIG. 3.—Areolar tissue

Areolar tissue is made up of branching connective tissue cells (*fibroblasts*) connected together by elastic fibres which are so numerous that they form a very fine meshwork interlacing in all directions. This imparts the property of a " many-way stretch " to areolar tissue. Many other types of cells may be found within this tissue, but in general the matrix intervening between the fibres and cells occupies a far greater area than do the cells. This is the outstanding difference between areolar tissue and adipose tissue.

3. Cartilage

Cartilage is a firm elastic structure which is devoid of blood vessels, except at its perimeter. Originally almost all the foetal skeleton was made of cartilage which later became bone. But some of the cartilaginous structures of the body failed to turn into bone and these few remained as cartilage. Such structures as the ear, the nose, the larynx, the cartilages on the rib ends and in the joints are examples of this, although they have different functions to perform and therefore have a different structure. Nevertheless, all cartilage has two outstanding features, (*a*) its matrix has been solidified by the addition of calcium salts and (*b*) it has retained its elasticity to some extent. The combination of these two features has no functional significance in any other human tissue.

Cartilage is classified as :

(i) **Hyaline cartilage** which has nucleated cells generally arranged in groups of two or more interspaced with a clear structureless matrix. It receives its nourishment from the fluid of the blood near its surface. Examples of hyaline cartilage are to be found at the ends of bones, the costal cartilages of the ribs and in the wind-pipe.

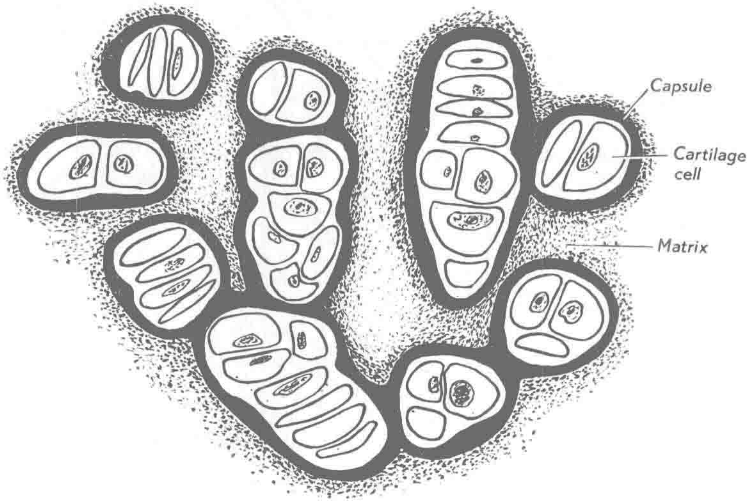

FIG. 4.—Hyaline cartilage

It serves as a protective buffer upon the pressure points at the ends of bones in contact with adjacent bones. Therefore, it must be tough as well as resilient.

(ii) **White fibro-cartilage** which contains much dense white fibrous tissue amongst which are scattered some groups of small cartilage cells around which there appears to be a " corona " of matrix, possibly secreted by the cells themselves.

This type of cartilage is found between the vertebrae as discs. They are also seen in the knee (the " cartilages " which get torn or displaced) and between the sternum and clavicle and in the wrist joint.

(iii) Finally, there is the **yellow elastic cartilage** to be found in the ear, larynx and epiglottis, where there is an abundance of double cartilage cells and less fibrous matrix than in other types of cartilage. The fibres are often continuous with those elastic fibres of adjacent areolar tissue. This is not a weight-bearing cartilage but its mobility must be ensured in the larynx and epiglottis and in the ears of animals.

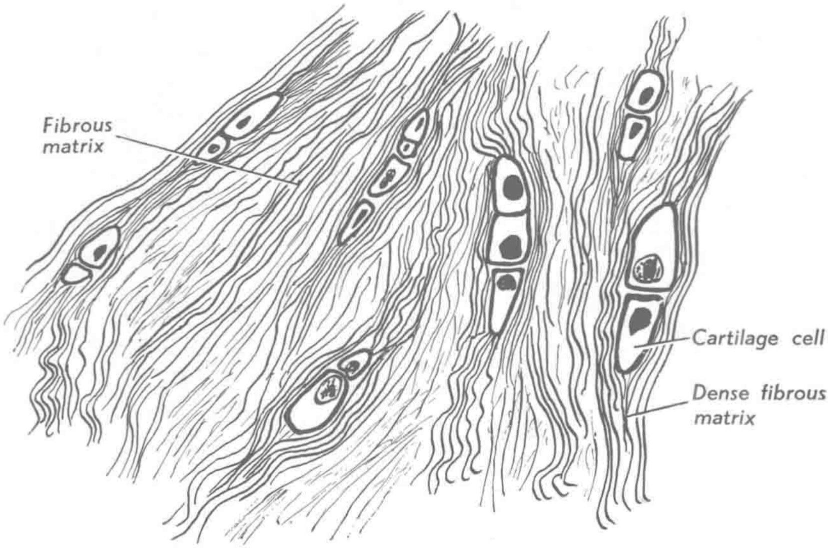

FIG. 5.—Fibro cartilage

4. Ligaments, fasciae and tendons

These important structures are made of a type of connective tissue known as ***white fibrous tissue***. This tissue appears as a glistening white collection of bundles of fibres. The few cells (*fibroblasts*) that are present are found on the surfaces of the bundles and are very thin. They possess long fibrous processes which project between the bundles in star-shaped fashion.

Fibrous tissue, because of its abundance of densely packed parallel fibres, is exceedingly strong ; it is devoid of elastic properties. Its functions are therefore to tether bones together and thus form the *ligaments* of the joint.

The bundles of fibres may be flattened out and form an envelope enclosing the joint surfaces of the bones—the *capsule* of the joint. Ligaments and capsules will thus contribute not only to the stability of the joints, but will also limit their movements to a required extent.

When this dense fibrous tissue is found around muscles it is known as *fascia* and is used in binding and protecting muscle fibres, separating them from adjacent muscles so that their action may be concentrated within a sheath thus formed. Fascia is thickest where great strength without elasticity is required, e.g. around the thigh muscles.

A *tendon* is a collection of bundles of white fibrous tissue connecting muscle fibres to their bony attachment. It contains a larger number of star-shaped cells within it and may be either flattened (an *aponeurosis*) as in the case of the external oblique abdominis or rounded as in the biceps brachii. A tendon whether flattened or rounded is not directly attached

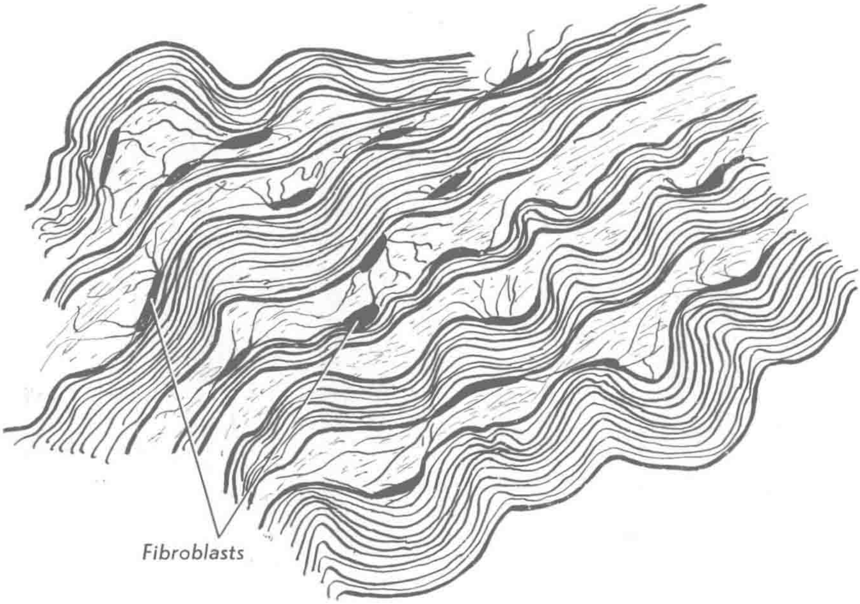

FIG. 6.—White fibrous tissue

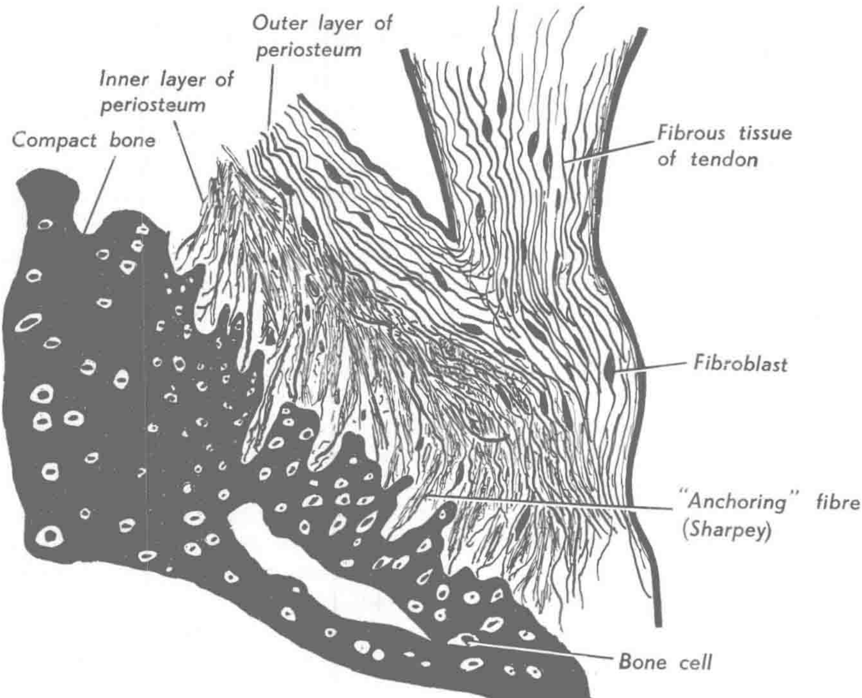

FIG. 7.—Attachment of a tendon to periosteum

to bony tissue, but rather to another strong ensheathing layer of white fibrous tissue around the bone known as the *periosteum*. This layer in turn is densely adherent to the underlying bone.

5. Bone

Bone, if it is to perform its functions adequately, must be *hard*. Certain bones are weight-bearing, e.g. pelvis, femur, tibia, calcaneum. Others act as levers for fine rapid movements, e.g. bones of the hand and wrist. Others afford protection to the structures encased within them, e.g. skull bones and the ribs ; while others combine weight-bearing with lever-movement for locomotion, e.g. lower limb bones. Thus it must be apparent that the connective tissue (cartilage) from which the long bones were developed must become impregnated with some hardening substances in order to form a rigid structure capable of carrying out the rigorous functions of support and movement of the body. The hardening substances are the salts of calcium and phosphorus and to a lesser degree of sodium and magnesium. The remaining composition of bone being approximately 33 per cent organic matter.

The outside of a typical bone is encased in two dense layers of periosteum whose functions are :

(*a*) to protect the bone
(*b*) to nourish the bone by sending small blood vessels into it
(*c*) to help in the formation of bony tissue
(*d*) to remould and limit the growth of bony tissue
(*e*) to form a mode of attachment for the ligaments and tendons to the bone.

Immediately inside the periosteum is the *compact* or *ivory* bone. This is the hardest part of the bone and forms a plating all round the shaft of the long bone, it being thickest half-way down the shaft and gradually thinning off towards the ends of the bone.

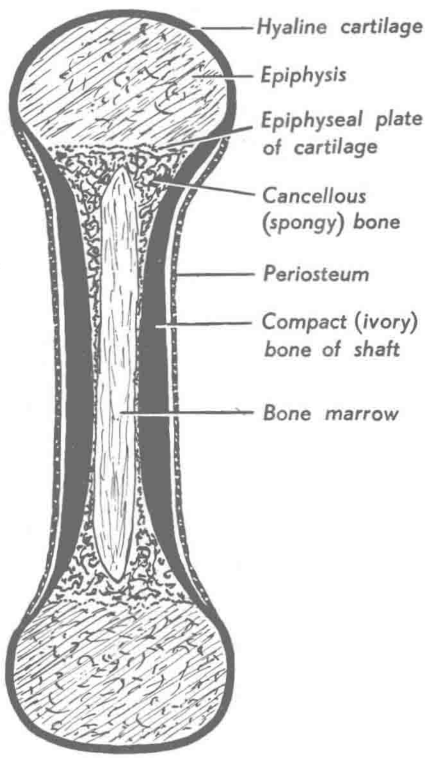

FIG. 8.—Longitudinal section through the shaft and epiphysis of a long bone