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THICKNESS OF THE ARTICULAR CARTILAGES

AT

DIFFERENT PERIODS OF LIFE IN THE HUMAN SUBJECT.

BY

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THEORY OF THE ABELIAN FUNCTIONS

CHAPTER I. THE ABELIAN FUNCTIONS

§ 1. DEFINITION OF THE ABELIAN FUNCTIONS

The theory of the Abelian functions is a branch of the theory of the functions of a complex variable. It is a generalization of the theory of the elliptic functions. The Abelian functions are defined as the functions which are periodic with respect to a lattice in the complex plane. The lattice is a set of points in the complex plane which are the vertices of a parallelogram. The functions which are periodic with respect to this lattice are called the Abelian functions. The theory of the Abelian functions is a very important branch of the theory of the functions of a complex variable. It has many applications in the theory of the algebraic curves and the theory of the algebraic surfaces.

§ 2. THE ABELIAN FUNCTIONS OF ONE VARIABLE

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THICKNESS OF THE ARTICULAR CARTILAGES, ETC.

OF the various phenomena presented to us by a living being, there are perhaps none more interesting, nor more strikingly illustrative of the action of the vital forces upon the tissues, than those of the development of different structures from the same primitive blastema, or from the same blood. What is the precise nature of the process by which a certain amount of material is converted in one position into bone, in another into muscle or nerve, it seems entirely beyond the reach of our present faculties to comprehend. We are, therefore, limited to the determination of the particular modes of development of different tissues, and the general laws which may be deduced from them. In such inquiries, nothing is more likely to lead away from the truth than prejudice in favour of a particular doctrine or system, nor does anything more surely obstruct the progress of science, or more certainly lead to the sacrifice of valuable time, than the existence of conclusions drawn by previous observers or authors from data which were not sufficiently accurate or extensive.

In investigations into the structure of healthy and diseased cartilage, commenced in the year 1848, and continued since that time, I have often been surprised at the statement that the thickness of articular cartilages gradually diminishes as life advances, owing to the conversion of the cartilage into bone; and my object in this contribution to the history of articular cartilage, is to show how far that statement is strictly accordant with facts. I do not hesitate to state that my earliest impressions were, that articular cartilages do not become gradually thinner as life advances, for I had observed them very thick in the aged on many occasions, and spongy and fibrous in old people generally. As such observations increased in number, I at length resolved to test the matter fairly, and with that view, I made a large number of measurements of the cartilages of various joints at different ages, at a great sacrifice of time and labour when compared with the importance of the result.

If the thickness of the articular cartilages concerned merely their

amount of elasticity, and their adaptation to the uses of the parts of the body to which they belong, it would be of great importance to know precisely what changes take place in them as life advances. We know that the bones and muscles of the aged person are very different from those of the young adult, and it might be expected that the cartilages would also be found changed, or, if they should not be so, we should look for some cause for this exemption in the case of tissues made use of for the same general purposes as the bones and muscles, and intended to harmonise with them in their action.

But if the assumed diminution in the thickness of articular cartilage with advancing age, be made use of as an argument in illustration of the nature of changes which take place in another texture, in the development of bone, it becomes doubly important to determine what grounds there are for the assumption which is thus founded on, lest another investigation be complicated by the introduction of erroneous data, which must be shown to be such before any considerable progress can be made.

Let us first examine the statement itself, and the authority on which it is founded ; secondly, What use has been made of it in the study of the development of bone ; and, lastly, The results of actual measurements of the thickness of articular cartilages at different ages, in a great number of instances.

Mr Toynbee, in his admirable paper "On the Organisation and Nutrition of Non-vascular Animal Tissues," read before the Royal Society, and published in the *Philosophical Transactions*,¹ says :— "The articular cartilage . . . is gradually being converted into bone during the whole of life ; thus, it is thicker in young than in old subjects, and, as Sir Benjamin Brodie informs me, it is much thinner in old age than in the adult ; in fact, it is not very rare to find that the articular cartilage of the head of the os femoris, in many old persons, has completely disappeared—a change which is probably to be attributed to its entire ossification. In a note, Mr Toynbee adds :—"This appears to be another of the many instances of the disappearance of the animal, and the increased deposit of the earthy, constituents of the body in old age." And again, as one of seven leading facts which Mr Toynbee believes that his researches tend to establish, he gives the following :²—"Articular cartilage, during the whole of life, gradually becomes thinner, by being converted into bone."

Dr Carpenter, after speaking of the normal proportion in the length of a bone being almost wholly acquired by the growth of the cartilage between the shaft and the epiphysis, says :³—"What further increase it gains seems chiefly, if not entirely, due to the progressive ossification of the articular cartilage covering the ex-

¹ *Philosophical Transactions* for 1841, Part I. p. 167.

² *Ibid*, p. 173.

³ *Principles of Human Physiology*, Lond. 1846, 3d edit., p. 151 ; and 4th edit. Lond. 1853, p. 266.

tremities, which progressively diminishes in thickness during the whole of life, and which in old age sometimes appears to have been almost completely converted into bone."

Thus it would seem that the statement made in Mr Toynbee's paper, has been the groundwork of Dr Carpenter's explanation of whatever increase takes place in the length of a bone, after the union of its epiphysis with the shaft. Then, as Mr Quekett states¹ that he found the articular lamellæ of the head of the humerus of a female, aged nineteen, "so very thin as only occasionally to be recognised," whilst the same part in a woman of upwards of seventy years of age was "of great breadth."² The conclusion which the reader of these statements is very likely to draw is, that articular cartilages become thinner, whilst the articular lamellæ thicken, these changes being probably proportionate to each other. Such a conclusion has not been deliberately announced; but if it be true that articular cartilages uniformly become thinner, and the articular lamellæ as uniformly and gradually thicker, as life advances, it would be perfectly warrantable to go much farther than this, and to affirm that the diminishing thickness of one tissue, and the increase in the other, are owing to the conversion of one into the other, or to the replacement of one by the other,—*i. e.*, to one or other of those actions which we know takes place in the ordinary formation of bone.

But let us inquire *whether articular cartilages uniformly and progressively diminish in thickness as life advances or not.*

At the commencement of the inquiry, it must be observed that there are many occurrences which prevent the conclusions which may be drawn from measurements of the articular cartilages in different bodies from being as absolute and as perfect as many others. Scarcely any tissue is more speedily changed in bulk by the absorption of water into its substance, or by desiccation. The thickness of an articular cartilage can only be measured after a section has been carried through it and the bone which it covers; and the making of a large number of such sections and measurements is attended with a great expenditure of time and labour. Measurements must necessarily be taken considerably after the middle of life, and at that age it is difficult to meet with corresponding parts of large articular cartilages free from the changes which I have elsewhere³ described as a process of anormal nutrition, and which may, with great propriety, be styled *senile degeneration of cartilage.*

¹ Histological Catalogue of the Royal College of Surgeons of England, vol. i. Lond. 1850, p. 130-131.

² "Nearly twice as broad" are Mr Quekett's words, in his Lectures on Histology, London, 1852, p. 148, in a comparison of the thickness of the articular lamellæ of the head of the humerus of a female of upwards of seventy years of age with that of one of nineteen,—most likely referring to the same sections as are described in the Histological Catalogue.

³ Anormal Nutrition in the Human Articular Cartilages, with Experimental Researches on the Lower Animals. 3vo. Edinburgh, 1850.

Nevertheless, though the difficulties of obtaining a series of perfectly correct measurements are very considerable, it will not be doubted that the plan which I have followed is more likely to lead to the truth than that of judging from general impressions of the thickness of the articular cartilages in a series of cases examined merely by the eye, and without any definite standard of comparison.

The results of my measurements of the articular cartilages of a series of bones I have embodied in a table which is hereto appended. The thickest part of each cartilage was uniformly chosen for measurement on account of the greater facility of referring to this than to any other part in the different instances. By reference to the table the thickness of a particular part of a certain number of cartilages may be compared at different periods of life, and though the number of measurements is not so great as might be wished, many of them have been made at such ages as would most satisfactorily lead to the determination of the difference of thickness, if any such difference do actually exist at different periods of life.

It will be noticed that the greatest number of observations has been made upon the cartilage of the head of the femur and those which enter into the formation of the knee-joint, which is accounted for as follows. The greater size and thickness of these cartilages appeared to point to them as instances in which the most accurate measurements might be made, whilst their greater importance seemed to indicate that additional information regarding them would prove more acceptable than if similar information were obtained regarding the cartilages of less important joints. I anticipated no difficulty in the application of the conclusions drawn from the examination of the largest and most important cartilages in the body, to those of less size and importance, and I therefore commenced my examinations by directing special attention to the cartilages of these large joints. After making several measurements I was reminded of former observations on the change of structure of cartilage as life advances, and of the greater liability of these very cartilages to such changes, by finding them frequently so much altered after adult age, that to measure them with great accuracy was entirely out of the question. I had no longer any predilection in favour of measurements made on the cartilages of these joints, and I subsequently examined those of the smaller joints as frequently as those of the larger ones. I would rather place confidence in measurements of the thickness of the cartilages of the smaller than of those of the larger joints in advanced life for the reasons just named.

The table shows a greater variation of thickness in the different measurements of the cartilages of the femur and upper part of the tibia than of any others, and I account for this by the fact that the cartilages of those parts are most apt to become soft, velvety, and fibrous, in which state it is quite impossible to determine their thickness with accuracy.

Notwithstanding the greater variation which occurs in the different measurements of the thickness of these large cartilages than of others, it will be found that there is nothing, either in these or in the smaller variations, observed in the other instances, nor yet in the whole series of measurements, which will warrant the conclusion that these structures become gradually thinner as life advances, nor even that they are thinner in the aged than in the young person.

From a conversation with Mr Toynbee on the statement made in his paper before referred to, I found that his evidence on this matter had been derived from the observations and statements of others, rather than from measurements or observations of his own, and thus I believe that he has been thrown off his guard, and made to appear as the author and supporter of a statement which, under other circumstances, his habitual care and anxiety to arrive at the truth, would effectually have prevented from being made in so definite a manner.

In conclusion, I may state my conviction, founded on the measurements indicated in the table appended, that *articular cartilages do not become gradually thinner as life advances, and that they are not uniformly thinner in aged persons than in early life.* I may also remark that, in endeavouring to estimate the thickness of articular cartilages at different periods of life, I have had presented to me a large amount of evidence in addition to that which I formerly made public, that, as life advances, these structures, and especially those of certain joints, change their elementary characters, and become fibro-cartilaginous, or altogether fibrous. This change has its analogues in the conversion of the costal cartilages into bone, of tendons into fibro-cartilage and bone, and in those changes which age induces in the bones generally, in the cornea and other tissues. It may not improperly be styled *senile degeneration of cartilage.*