D. J. Wyman,
with the author's respects

ON THE

INTIMATE STRUCTURE AND HISTORY

OF THE

ARTICULAR CARTILAGES.

BY JOSEPH LEIDY, M.D.

(WITH TWO PLATES.)

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THE structures entering into the composition of a movable joint, or articulation of the animal body, exhibit the same wonderful adaptation to the end in view, which we see displayed everywhere else in nature.

Joints are absolutely necessary to locomotion, in an animal possessing a skeleton or hard basis of support for the softer organs, for it is by means only of the different segments of the skeleton, whether internal as in the vertebrata, or external as in insecta, crustacea, &c., moving upon each other, through the power residing in the muscles, that all locomotion is produced. If we conceive of one of the higher mammalia, say of man, formed with a skeleton in one piece, at once it alters his whole character. He becomes fixed to one position, the muscles ordinarily concerned in acting upon the segments of the skeleton are no longer of any use, and may be dispensed with. Respiration as ordinarily carried on must cease, the nerve centres concerned in directing the movements would be no longer required,—in fact the animal could not exist as such; but if its vascular system could be prolonged into a soil of nutritive matter, and respiration be carried on at the surface of the body, although ceasing to exist as an animal it would do so as a plant.

If the skeleton be dispensed with, we may have a body capable of moving from place to place, by alternate contraction of different parts of the mass, as in a slug (Limax), but the sphere of locomotion of such an animal is necessarily very limited, and could not exist with the well characterized intelligence of an animal higher in the scale.

The movable articulations of the human body are numerous, and present every variety of form of surface in their construction. The articulating surfaces are usually formed upon the expanded extremities of the bones, but in no instance, in a normal condition, do we find the osseous structure entering immediately into their formation, but the opposed surfaces of the articular extremities of the bones are covered by a lamina of elastic substance, the articular cartilage, which possesses a degree of vitality inferior to that of bone. To this form of cartilage I have more particularly directed my attention, and its history and intimate structure are the subjects of the present memoir.

The perfectly formed or adult articular cartilages are closely moulded upon the articular extremities of the bones, and are inseparably adherent until removed by maceration in dilute muriatic or other acid, when they are readily detached, presenting a surface corresponding to that of the bone from which they were removed; being rough, and presenting beneath a lens, a number of ridges, conical projections and pits, all of which are for the closer adaptation of the structure to the bone. From the foregoing facts, these cartilages are called also cartilages of incrustation.

The free surface of the articular cartilages, or that presented to the interior of the joint is very smooth and glistening, exactly fits the surface of the opposed cartilage, and leaves no interval, except where interarticular cartilages, or synovial doublings, are introduced, and is kept constantly bathed in synovia, the peculiar unctuous serous fluid of the articulations, which, added to the elasticity of the structure, permits these surfaces to move freely and easily upon each other with the least possible degree of friction and attrition, and with the least liability to danger of abrasion; all of which would occur to a comparatively great extent, if the harder and less elastic surfaces of the bones were to come in immediate contact.

The articular cartilages vary in thickness in the different articulations, being thickest in those which are most movable, and most subject to attrition. The greatest thickness they reach, which is in the knee or hip-joint, is from one and a half to two lines. An articular cartilage also varies in thickness, in different parts of its extent, and thus its two surfaces are never entirely parallel with each other, for, as a general rule, upon a convex articular face of bone we find the cartilage forming a thin edge at its circumference, and gradually becoming thicker towards the centre, and upon a concave surface the reverse arrangement taking place, being thin in the centre, and gradually increasing in thickness towards the circumference, where it is again reduced to a thin edge.

When separated from the bone, the articular cartilage may be readily bent double without breaking, and in fact it usually requires some force to break it. The course of the fracture is always perpendicular to the surfaces, and the broken edge presents a fibrous appearance, in the same direction, and in some cases it appears laminated, especially near the free surface of the cartilage.

Articular cartilages are of a pearly white colour; where thin they are opalescent or bluish white and translucent; sometimes they have a tinge of yellow, which is occasionally deepened, apparently by the imbibition of colouring matter from the synovia; more rarely they present a pinkish tinge.

From their firmness, toughness, flexibility, and high degree of elasticity, besides being less liable to abrasion or other accident, the articular cartilages perform an important function in diminishing the violence of blows or shocks, under many circumstances, serving as so many points of reaction when the extremities of the bones are suddenly or violently forced against one another, as in falls upon the feet, &c.

They are totally non-vascular; the arterial vessels in their vicinity, after approaching their attached surface and circumference, turn back to the venous trunks. The vascular circle formed at the circumference of the articular cartilage was called by Wm. Hunter,* the *circulus articuli vasculosus.* The blood-vessels of this circle pass a little way over the edge of the cartilage, and stop a little short of the angle formed by the attachment of the synovial membrane to the latter. These vessels are convoluted, and form loops which are much dilated, an arrangement first pointed out by Mr. Toynbee.† The vessels which approach the attached surface of the cartilage, according to Mr. Toynbee,‡ are numerous and large, and are separated from it by a delicate lamella of bone.

The advantage which the articular cartilages possess in their non-vascularity is very great, in their immunity from the many accidents which a vascular tissue would be liable to in a similar position, where the parts are so much exposed to sources of irritation.

Nor is it probable that lymphatics exist in them; their vital activity is not very great, and if there is any interstitial destruction at all, the molecules so separated, may exosmose from the cartilage dissolved in the effete fluid derived from the nutritive fluid of the tissue.

These cartilages are destitute of nerves;—at least they are perfectly insensible, for I have several times sliced away, wrenched, torn, and twisted the articular cartilage from the head of the tibia of a rabbit and a cat, without the animals evincing the slightest indication of pain, and although I have followed the course of filaments from branches of the articular nerves as far as the fine areolar tissue at the edge of the articular cartilages, yet I have never been able to detect the slightest appearance of a filament entering the cartilaginous structure.

Intimate Structure of the Articular Cartilaginous Tissue.—The older anatomists considered the articular cartilage to be homogeneous in its character, or to be composed of fibres arising from the surface of the bone, and terminating at the free surface of the cartilage, which condition was proved by the latter always breaking in a determinate direction, the fractured edge presenting a fibrous or columnar appearance, comparable to the arrangement of the enamel structure upon the body of the tooth, and from its being resolvable into

* Of the Structure and Diseases of Articular Cartilages, by Wm. Hunter, Surgeon. Phil. Trans., vol. xlii. 1742–43, p. 514. London.

† On the Organization and Nutrition of Non-vascular Animal Tissues. Phil. Trans., 1841, p. 159. London.

‡ Ibid., p. 173.

separated filaments by maceration. How far this opinion is true will be seen in the course of our investigations.

When a thin section of the articular cartilage is submitted to the microscope, two distinct parts, or structures, are observable in it; organic cells, or cartilage cells or corpuscles, and an intercellular substance, or matrix.*

Cartilage Corpuscles, (Plates I. and II.)—These bodies are solid nucleolo-nucleated cells, imbedded in the cartilage matrix, and varying in a slight degree in different parts of the articular cartilage. A few of them are single or isolated, but most usually they are found in groups of two, up to twenty-two, the latter being the highest number I met with. The groups are arranged in single, double, triple, or quadruple rows, the direction of which, in the deep part of the cartilage, or that nearest the surface of attachment, is perpendicular (Plate I. Fig. 1, *e*) to the surfaces, for the most part, but as they approach the free surface, they become more or less oblique (*d*) and even irregular, and finally, near the free surface, become parallel (*c*) with the latter, or at right angles with the deeper groups. The arrangement of the cell groups is considered by most modern anatomists to be the cause of fracture of the cartilage, in a determinate direction; perpendicular to the surfaces in the deeper part, and parallel with the same at the free surface. The groups of cells are comparatively few in number in the deep part of the cartilage, or the intervening matrix is in greater abundance, but they gradually increase in number as they approach the free surface, near which they are found quite crowded, and with little intervening matrix.

The deeper groups (Plate I. Figs. 2 and 3) of cells are composed of a greater number of individual cells, than those existing more superficially, and in the stratum of cartilage forming the free surface, (Plate II. Fig. 1,) single or isolated cells are more numerous than in any other part of the cartilage, and the most frequent groups are composed of two or three cells,—rarely a group containing more than six is found.

The cells when single or isolated, are round or elliptical in outline, but when grouped, they are flattened or have the appearance of compression upon the sides presented to each other, and rounded at the circumference of the group, with the two end cells frequently elongated, or even brought to a point.

* A striking analogy exists between the articular cartilaginous structure, and some of the algous forms of vegetable life; thus, the Conferva mucosa? Mert, (*Harvey, Manual British Algæ, London,* 1841,) which is found growing in the little stream running through the swamp at Kaign's Point, N. J., just below Philadelphia, consists of filaments or rows of cells enveloped in a transparent mucoid substance, corresponding to the cell groups and matrix of the articular cartilage. The cells are sometimes filled with endochrome, in other instances the latter is contracted into a mass occupying the centre of the cell, while the interspace is filled with transparent matter, and the endochrome contains a nucleus rendered visible by iodine, in all which respects exhibiting a resemblance to the analogous points of structure of articular cartilage.

In the deeper part of the cartilage, the diameter of the cells in different directions varies but little, and averages the $\frac{1}{2000}$th of an inch in their long diameter, and the $\frac{1}{2270}$th of an inch in their shortest diameter; but in the superficial stratum of cartilage, the cells or groups of cells (Plate II. Fig. 1, and Fig. 2, *a*) are much flattened parallel with the surfaces of the cartilage, appear large and broad when viewed in this direction, and measure upon an average the $\frac{1}{900}$th of an inch long, while the edges of the cells or groups, when viewed in a vertical section of the cartilage (Plate II. Fig. 2 *b*, and Fig. 3,) appear very narrow and lenticulo-linear in outline, and measure in thickness on an average $\frac{1}{2270}$th of an inch.

When a thin section of the cartilage is viewed beneath the microscope, the cell-groups are observed to produce a shaded ring, in their vicinity, in the matrix, and when well-defined, they appear surrounded by a clearer or more translucent wall or outline than the matrix; but when within the focus a little, they appear surrounded by a dark outline or boundary. The outlines of the individual cells, where they approach, or are in contact in the groups, are often indistinct, but may always be distinguished by a shaded line passing in and indicating the interval.

In structure, the cells present points of difference in different parts of the cartilage.

The cell wall appears blended or fused with the intercellular substance, and can be studied as a distinct structure only in the very early condition of the cell.

The cell contents (Plate I. Figs. 2 and 3) usually consists of a translucent homogeneous, or at most an indistinctly and very minutely granular substance, with a more or less central mass of distinctly coarser and darker granular matter, which is generally considered to be the nucleus, but the true character of which will be indicated hereafter. This mass contains a transparent, round or oval nucleus, which is brought into view and coloured brown, by the application of tincture of iodine. The mass also frequently contains fat granules or globules. It is larger in the more superficial than in the deeper cells, measuring in the former on an average the $\frac{1}{2900}$th of an inch in diameter, in the latter, the $\frac{1}{3448}$th of an inch. Generally the more superficial layers of cells have not this isolated mass, but are filled (Plate II. Figs. 1, 2, and 3) with finely granular contents interspersed with numerous darker and well-defined granules measuring about the $\frac{1}{21739}$th of an inch. These granules have a black outline, resembling very much fine fat granules, and some of them appear to be really such, for after macerating the cartilage a few days in water, I have noticed a number of them to become aggregated into one or more globules having all the appearances of oil. In these superficial cells the nucleus is large and distinct, round or elliptical, very finely but distinctly granular, and contains about its centre a transparent, but often indistinct nucleolus. In some instances I have noticed the larger and distinct granules of the last mentioned cells forming a circle (Plate II. Figs. 1, 2, and 3), more or less broken or defined, a short distance from the nucleus, and giving the latter the appearance as if contained within a larger but much less distinct nuclear body. Sometimes this arrangement is quite distinct, but usually it can be but faintly seen.

In other cases the cells of the superficial stratum of the cartilage present the same appearance as the deeper cells, excepting that they are more flattened in a direction parallel to the surface, and the interior granular mass is larger.

In not unfrequent instances, I have noticed in the most superficial stratum of some of the articular cartilages, large, flattened cells, or cell-groups, sometimes with the outline indistinctly delineated, and with nothing distinguishable, excepting finely and indistinctly granular contents, appearing like cells which have been rubbed out in the attrition of the opposed surfaces of the cartilages.

Less frequently I have observed immediately beneath the free surface of the cartilage, and too deep to be influenced by friction, cells (Plate I. Figs. 7 and 8) large and flattened, most usually isolated, or in pairs, finely and indistinctly granular, without apparent nucleus or other more distinct body, or with the apparent formation of a nucleus from the aggregation of the finer granules around a larger, transparent, and very distinct granule or nucleolus. The nuclear appearance was most distinct in the paired cells. What is the character of this variety of articular cartilage cells? Are they cells in the process of development?

Cartilage Matrix, or the intercellular substance of the articular cartilage is, as previously mentioned, in comparison with the cartilage corpuscles, most abundant in its deeper part. It is in thin sections translucent, but not to the same extent as the cell contents between the cell wall and central mass, when the latter exists, and it usually has a faint yellowish hue. Most commonly it has a more or less finely granular appearance, and has generally been described as a homogeneous hyaline, or a finely granular substance, but although it may have the latter as an ultimate arrangement, yet from numerous and carefully repeated observations, I am fully convinced that it has a filamentous structure.* These filaments (Plate I. Fig. 4) are exceedingly fine, but possess considerable strength, and are pretty uniform in size, having an average measurement of the $\frac{1}{25000}$th of an inch in diameter. The largest I measured, which are few in number, measured the $\frac{1}{20000}$th of an inch, the smallest, the $\frac{1}{30000}$th of an inch. When viewed by light thrown upon them with considerable obliquity, they appear faintly granular, each filament composed of a single row of very fine granules. Acetic acid produces no apparent influence upon them; potassa renders them more translucent and faint; and iodine stains them yellow.

* Proceedings Academy of Natural Sciences of Philadelphia, vol. iv. No. vi., 1848.

These filaments lie parallel with one another, they adhere very tenaciously together and under ordinary circumstances are hardly demonstrable, although I have occasionally seen them at the ends of a torn shred of articular cartilage. But if an articular cartilage be taken from a bone which has undergone maceration in diluted muriatic acid to remove its earthy constituents, and be broken, and from the fractured edge a fibre or shred delicate enough to transmit light, be torn off with a pair of fine-pointed forceps, and be submitted in the ordinary manner to the microscope, using the one-fourth or one-twelfth of an inch object glass, numerous, detached and exceedingly delicate, spider-thread-like filaments will be readily detected along the whole length of the sides of the shred. In making this observation it may be frequently noticed, that in tearing off fine shreds of the cartilage, if a group of cells has been in the course of the rupture, it will be torn through, which alone would be sufficient to indicate that the fracture of articular cartilage in a definite direction does not depend upon the arrangement of the cell groups. Besides this, straight fibres are frequently torn loose in the deeper part of the cartilage where the matrix is most abundant without coming in contact on either side with cell groups, and it is now sufficiently evident that the latter have little or no influence in determining the course of fracture, but that it is entirely due to the filamentary arrangement of the matrix.

This filamentous structure of the articular cartilages, though not so intimately understood as presented above, was nevertheless pretty satisfactorily known to exist; "thus," Wm. Hunter says, "we may compare the texture of a cartilage (articular) to the pile of velvet, its fibres rising up from the bone, as the silky threads of that rise from the woven cloth or basis;"* and M. de Làsone also says, "si l'on veut examiner le cartilage qui encroûte la tête du fémur, il faut commencer par diviser verticalement cette tête en deux parties, et les soûmettre ensuite à la coction; alors on reconnoît que l'arcade ou l'espèce de ceintre que forme la portion cartilagineuse qui encroûte l'os, n'est qu'une multitude des petits filets adossés et liés les unes aux autres, tous perpendiculaires au plan de l'os."† Mr. W. Hunter also supposed the perpendicular fibres to be held together by transverse ones so as to "make the whole a solid body," and these "being very tender," in macerating the cartilage, they are destroyed, leaving the perpendicular ones detached from one another. No filaments of this character are to be detected by means of the microscope.

It is well known that if an articular cartilage be forcibly broken through, the fragments will adhere by a thin stratum of membrane covering its free surface. This membranous layer is readily detached by tearing the fragments from each other, and it was considered by the older anatomists to be the synovial membrane. Having all the characters of cartilage, its disposition by

* On the Structure and Diseases of Articular Cartilages. By Wm. Hunter, Surgeon. Philosoph. Transac., vol. xlii. p. 514. London, 1742, '43.

† Second Memoire sur l'organisation des os. Par. M. de Làsone. Mem. de l'Acad. Roy. des Sci., tom. 69, Paris, 1752.

modern anatomists, is believed to depend upon the arrangement of its cell groups, which, as before mentioned, are parallel to the free surface of the cartilage. But instead of its membraniform condition depending upon the course of its cell groups I find it to result from the structure of its matrix, which has also a filamentary arrangement like that of the deeper part of the cartilage, the filaments, however, taking a course at right angles to those of the deeper cartilage and parallel to the surface.

In neither case, then, do the groups or columns of cells determine the course of rupture of the articular cartilage, but on the contrary, it is the filamentary arrangement of the cartilaginous matrix which influences the direction of the cell groups, for in the development of the latter, from the division of the primitive or original cartilage cells, they take the direction in which there is least resistance, which would be in the direction of the length of the filaments of the matrix; hence, in the deeper part of the articular cartilage, as a general rule, we find the cell groups and filaments of the matrix both vertical to the surface but, in the superficial stratum, they are parallel to the surface or at right angles to the former.

Synovial Membrane in its Relation to the Articular Cartilage.—It has been a subject of much discussion among anatomists whether the free surface of the articular cartilage is covered by a reflection of the synovial membrane or not. Wm. Hunter, Sœmmering, Bichat, and many others assert and have tried to demonstrate its existence, but they have evidently mistaken the lamina of cartilage forming the free surface of the articular cartilage for it, while Cruveilhier, Magendie, Velpeau, &c., doubt its existence from pathological and physiological observations. In my observations I have always failed to detect the slightest trace of synovial membrane, in the adult, upon the free surface of the articular cartilage, or even the appearance of a basement membrane; for in all cases, no matter how thin the lamina was which was torn from the articular surface, it presented the indistinctly granular, or, when treated as I have before mentioned, the finely filamentous structure of the cartilage matrix. It appears to terminate at the circumference of the articular cartilage a very little beyond or in advance of the *circulus articuli vasculosus.* In the fœtal state it exists in a very distinct state, covering the surface of the epiphysal cartilages, and may be readily distinguished by its flattened epithelial, nucleated cells, beneath which can also be readily detected a transparent, homogeneous basement membrane. But after birth in the progress of growth of the articular cartilages, it appears to be destroyed by pressure and attrition and probably from the retiring of the surface vessels towards the circumference. It appears to be progressively removed from the centre to the circumference of the cartilage, but always to remain a little in advance of the *circulus articuli vasculosus.*

Occasional Peculiarities in the Structure of the Articular Cartilages.—In several instances, I have noticed in some of these cartilages what appeared to me to be numerous minute lacunæ, and I have now in my possession an articular cartilage (Plate I. Figs. 2 and 4) from the condyles of an os femoris exhibiting this structure. They exist in greatest abundance in the deeper part of the cartilage, gradually decrease in number, as the free surface is approached, and disappear entirely in the superficial fourth of the cartilage. They are lenticular in outline, invariably situated with their long diameter parallel to the surfaces of the cartilage, or at right angles to the filamentary intercellular substance, in which they are directly placed. The longest measure the $\frac{1}{1200}$th of an inch, the shortest the $\frac{1}{3125}$th of an inch; the short diameter is about the $\frac{1}{6250}$th of an inch. When well defined, beneath the microscope, they appear more translucent than the cartilaginous matrix in which they are situated, and when viewed a little within the focus of the instrument, they appear deep black, or oppose the transmission of all light.

Another peculiarity (Plate I. Figs. 5 and 6) which I have occasionally noticed, is the existence of fibres or columns of bone penetrating the structure of the cartilage,—I have in my possession an articular cartilage from the head of an os femoris presenting this character. These fibres are generally found pervading the cartilage near its surface of attachment, but are not the continuation of the bony structure upon which the cartilage is placed, for they are invariably arranged in a direction parallel to the surfaces. They are quite uniform in shape and structure, being compressed, cylindrical, in transverse section presenting an elliptical figure the long diameter of which is placed parallel to the surfaces of the cartilage or at right angles to the filaments of the matrix in which they are situated. They are not numerous, and vary from a size not exceeding a cell group of five cells to the size of four or five such groups. They are concentrically laminated, and also present a radiated conformation, resembling somewhat the structure of an Haversian ossicle, but neither present the canal nor the Purkinjean corpuscles.

Development and Growth of the Articular Cartilages.—The articular cartilages as a distinct structure are not perceptible so long as the epiphyses and articular extremities of the bones are not ossified, consequently they do not exist during fœtal life or for a considerable period after birth. At birth if an epiphysal extremity of a long bone be cut vertically through, it will be observed that the cartilage of the epiphyses extends to the synovial membrane and that there is not the slightest trace of a line of demarcation between the two varieties of cartilage. If the section be more carefully examined, a number of branching canals will be observed ramifying through the cartilage, many of which approach its articular surface but are in all cases separated from it by a thin lamina of the cartilage containing no canals. This thin lamina is the first appearance of the articular cartilage, but presents no distinction of structure at this period from the mass of cartilage of the epiphysis. The canals of the epiphysal cartilage contain blood-vessels, which, according to Mr. Toynbee,* have a very peculiar disposition, consisting of arteries terminating in dilatations, or in convoluted branches, from which the veins arise. In the process of ossification and increase in size of the epiphysal cartilage, the developing articular cartilage appears to be pushed before it, resulting from an interstitial growth depending upon the division of the primary cartilage cells, the probable development of others, and the increase of the matrix or intercellular substance. When the articular surface cartilage (Plate II. Fig. 5) of a cartilaginous epiphysis is examined microscopically, it is found to have all the characters of the latter, and at an early period of fœtal life consists of a translucent, hyaline substance, in which are diffused with considerable uniformity, rounded or elliptical, isolated, nucleolo-nucleated cells, separated from one another by interspaces less than their own diameter. They vary to a moderate degree in size, and average about the $\frac{1}{1785}$th of an inch in diameter. The cell contents forms a mass rather darker than the intercellular matrix, the reverse of what is the case in the perfected articular cartilage. It is finely granular, with an intermixture of coarser and more defined granules, some of which appear to be oleic in character. The nucleus is round or oval, varies a little in diameter, averaging about the $\frac{1}{3570}$th of an inch, and is very finely granular in structure. Sometimes there are two nuclei, sometimes separated and distant, at others, approached, flattened upon the opposed sides, and apparently having originated from the division of a single nucleus. The nucleus contains a more consistent, translucent nucleolus, readily brought into view by the tincture of iodine, and measuring about the $\frac{1}{11111}$th of an inch. The intercellular substance is comparatively soft, very translucent, and homogeneous. As the articular cartilage advances in its development, the intercellular matrix increases in quantity, separating the cells at greater distances apart, and acquires a firmer consistence. It becomes faintly granular, which after a time becomes more decided, though indistinct at any time without a good defining power, and finally takes on the peculiar filamentous arrangement described in a previous part of this memoir.

But the question arises how does this intercellular substance increase in quantity? Is it a direct deposit of imbibed matter from the liquor sanguinis in the vicinity of the cartilage, or is it produced through the agency of the cartilage corpuscles, or organic cells of the tissue? Recollecting that the liquor sanguinis does not contain dissolved cartilage, it cannot be a direct deposit; but may not the cartilaginous molecules already produced, convert an assimilative substance into molecules of a similar character, chemical and physical? The latter is probable, but it is easier to suppose it to be formed from imbibed albumen, through the agency of the cartilage cells, in the same manner that it originally results from the albumen ovi, probably through the agency of cells, the earliest cartilage cells, which have been the offspring retaining part of the organizing force of the Purkinjean vesicle. As it is

* Phil. Trans., 1841, p. 166.

certain that cartilage tissue is produced from albumen, it is worthy of inquiry whether the organic cells of the cartilage are capable of fixing a material thus transformed in their vicinity. If it can be demonstrated that such a power exists in organic cells in any part of the organic kingdom, we may feel assured that it prevails throughout. Turning back then, in vitality's great book, to the first few pages, we discover some very simple expositors of the question at issue. Thus, if we examine several of the families of Chlorospermeæ, the oscillatoriæ, ulvaceæ, nostochineæ, &c., we find numerous zooid plants, some of the simplest forms in the organic kingdom, consisting of single rows of organic cells, enveloped in a mucoid substance, and swimming in water or flourishing in humid situations. When the green spores, single organic cells filled with endochrome and containing a nucleus, are discharged from a parent cell, they accumulate and fix around themselves a mass of mucoid substance from the nutritive matter floating in the element around them. The spore develops a perfect plant, a mere filament or row, or a lamina of cells, continues to accumulate mucoid matter around it, until the latter is frequently several times the diameter of the plant itself. Retaining its organic activity it produces spores, which are to be discharged, and undergo the same progressive changes. Perceiving, then, that these cells can collect and fix matter around them, and continue to operate upon imbibed nutritive fluid, it is rendered probable that an analogous process may be carried on in the denser cartilage, since the latter, as is well known, is capable of imbibing nutritive fluid.

Whether the surrounding matter is formed within the cells and then exosmosed, or whether the cell life extends its formative power beyond the precincts of the cell wall, remains a question, but I think both are probable.

The cartilage cells at the early period of development are easily detached from the matrix, but at a later period the cell wall fuses or blends itself with the intercellular substance, but even after this the granular cell contents is easily detached in a single mass (Plate II. Fig. 4), appearing to be retained together by a delicate protoplasmatic envelop, corresponding to the primordial utricle of vegetable cells. Of the existence of such a structure in some animal cells I am well convinced, and hope to prove in a future memoir on the subject.

After the cartilage matrix has taken on itself the granulo-filamentous structure, the cartilage cells increase in number by division, and probably also by the origination of new cells. In studying the development of the groups of cells of the perfected articular cartilage, the steps of progress, as noticed at several periods during the growth of the latter, appear to be as follows:

The simple isolated cartilage cells are found to become somewhat elongated, (Plate II. Fig. 6,) then at the sides to present the appearance of an indentation. The nucleus has a central position, and then a faint dividing line, (Pl. II. Fig. 7,) more translucent than the other parts of the cell, is observed crossing the short diameter of the cell, resembling somewhat the transverse line of dehiscence of an ovisac. By varying the focus of the microscope, it is found that this line penetrates as a plane through the cell. The next change (Plate II. Figs. 8 and 11) which is remarked, is the retiring of the granular cell contents from the inner parietes of the cell wall, excepting where in contact with the dividing line of the cell. The cell wall has now become blended with the intercellular substance, and the latter also occupies a position between the inner surface of the cell wall, with which it also blends, and the retiring cell contents. The cell contents, (Plate II. Fig. 9,) at this period distinctly presents itself divided into two masses, corresponding to the previously mentioned line passing through the cell, and each mass contracts itself with the contained half of the original nucleus, towards the centre of its respective cell.

From the uniformity with which the granular cell contents contracts, holding all its contained parts together, granules, nucleus, and fat globules, I am strongly impressed with the idea that it has a protoplasmatic envelop or primordial utricle. In vegetable cells we frequently observe the same mode of retiring of the granules of endochrome retained together by the delicate, transparent, mucoid envelop, the primordial utricle, and, as is well known, this may be produced by artificial means, which I find to be also the case with the cartilage cells, for I have observed the cell contents slightly and very gradually contract in a single mass upon the application of tincture of iodine, or even under the long-continued imbibition of water.

Whether the division of the nucleus precedes that of the cell, or the reverse, still remains a problem. Cartilage cells are not unfrequently observed containing a nucleus apparently in progress of division, and others, with a pair of nuclei near each other, and flattened upon the opposed sides, having the appearance as if the result of division of a primitive nucleus, without the slightest trace of any disposition of the cells to divide themselves. In other instances I have detected cells presenting a slight parietal indentation, without any similar appearance of the nucleus, and in all other cases, when the cell exhibited signs of division, a corresponding change was invariably observed in the nucleus.

The pair of cartilage cells which have originated from the primary cell, increase in size by the assimilation of nutritive matter, and undergo the same division as just described, until groups are formed as found existing in the perfected cartilage. The cell contents continually retire, but at the same time appear to partake in the general nutrition of the cell, until in the cell group we find the masses generally central, frequently irregular in outline, and containing more or less oil globules, and one or two nuclei, and in this state have been generally mistaken for the nuclei of the cartilage cells.

The cells, in their progressive division, do so generally in the same line, but also very frequently divide, laterally, so that the pair of cells resulting from the division of the first, may either form a row (Plate II. Figs. 12 and 13) of four or a group of four, (Plate II. Fig. 10,) and continue in this manner. The cause determining the arrangement of the cells into rows instead of masses, has already been referred to; the least resistance to their extension being parallel with the filaments of the cartilage matrix.

The irregularity which exists in certain of the cell groups, especially in the stratum lying about one-fifth the thickness of the articular cartilage below its free surface, probably depends in some degree upon the pressure of the opposed cartilages of the joints. I do not mean by this that a sudden push would knock the deeper groups out of a vertical line, but I think during the progress of division of the cells and extension of the groups, a frequently repeated or moderately continued pressure exerted upon the free surface of the cartilage, would give them a tendency to incline to one or the other side, and hence their obliquity, or curved or irregular character from the ordinary line in a part of the cartilage most influenced by the pressure.

Of the Nutrition of the Articular Cartilages.—It has been already sufficiently proved (by the continual increase of the intercellular substance, and division and increase in size of the cartilage cells), that during its development and growth, the articular cartilage possesses an interstitial nutrition, but the question arises, after the cartilage is fully formed, is there a constant interstitial waste and repair of the cartilaginous element, as is the case in most organic tissues? M. Cruveilhier says, "les cartilages diarthrodiaux ne presentent aucune trace d'organisation,"* from which assertion it is evident that the existence of blood-vessels in a structure, is considered the necessity of organization, an error into which the older anatomists continually fell into. But we now are certain that these are only a provision for carrying a nutritive material within the sphere of action of those bodies which are the grand characteristic of organization, the organic cells, and that they are not necessary to organization, or even organic activity, but only to particular forms of it. It is the constant supply of a nutritive fluid which is essential to the active condition of the vital force residing in the organic cells, no matter whether the fluid be conveyed to them by channels (blood-vessels) excavated in the mass, or whether it be obtained by imbibition from the surface of the latter. Does not the stomach of a Hydra prepare a fluid as capable of digesting materials as that of man? and although the entire animal does not possess a single blood-vessel, who will say that this organ presents less the phenomena of organization than the corresponding one in man?

When an animal or plant is small, simple in structure, or possesses few and minute, or very simple organs, it is sufficient that the body or organs be bathed in a nutritive fluid, from the surfaces of which it may be imbibed, to present all the phenomena of vital action; but when the being becomes massive or complex, from numerous organs which are massive, blood-vessels become necessary, or rather channels which divide the masses into a surface of contact for the nutritious fluid, of greater or lesser extent, depending upon the

* Obs. sur les Cart. Diarth., *Arch. Gén. de Méd.*, vol. iv. p. 162.

degree of organic activity displayed by the organs, which is indicated by the amount of nutritive fluid they require.

If, then, we perceive an algous plant, or simply constructed animal, capable of obtaining nutritive matter from the water in which they are bathed, or the lichen from the rarer atmosphere in which it exists, without blood-vessels pervading their structure, is it not probable that in more complex animals we may have simple structures nourished in a similar manner? The articular cartilage appears to be such an one, without blood-vessels it is bathed by fluid exosmosing from the vessels beneath its attached surface, from the circulus vasculosus at its circumference, and especially by the synovia upon its free surface. I have said especially the synovia, an idea which may at first view appear preposterous, but which with a little consideration will appear at least quite probable.

We find all the conditions of a nutritive fluid due to the articular cartilage in the synovia, and it is particularly rich in albumen, the main element of nutrition of the cartilage.

From several experiments I find the articular cartilages are quite capable of imbibing the synovial fluid. Thus I collected the synovia from several joints of a calf in a vessel, and upon drying an articular cartilage, and then immersing it in the synovia, I found it gradually to imbibe the fluid, and resume its former appearance. Somewhat similar experiments I tried upon several living animals,—a rabbit and a pigeon. When a joint was opened, and the articular extremity of the bone protruded and allowed to dry, which it does pretty rapidly, upon reducing the dislocation, and examining it again after a little while, and cutting vertically through the articular cartilage, I found it had imbibed fluid from both surfaces, while a thin layer on the interior was still dry.

Another experiment showed me that imbibition takes place with considerable power in this tissue. I took four pieces of articular cartilage, each about one inch square, and two lines in thickness, permitted them to dry, by which they shrunk to a little more than one line in thickness, placed them in a vessel of water, and rested upon them a stage loaded with nearly ten pounds. The next day, upon removing the stage, I found the pieces had resumed their former bulk, thus having imbibed the water with a power sufficient to raise ten pounds nearly one line, and I have no doubt the power is much greater, but how much more so, it was not convenient at the time of my experiment to determine.

But, besides mere imbibition, we have all the conditions of that remarkable modification of the phenomenon, endosmosis, present in the articular cartilage, and even to its greatest intensity. Dutrochet proved long ago that albumen dissolved in water produces endosmosis with a degree of force not paralleled by any other organic substance, under ordinary circumstances.

The synovia presents a highly inspissated albuminous fluid separated by the articular cartilage from the much thinner liquor sanguinis of the vessels beneath. In such a condition, having proved the power of imbibition of synovia in the living animal, a constant endosmosing current must exist from without, and an exosmosing one from within.

Having introduced some saturated solution of ferrocyanide of potassium into the articulation of the knee of a living rabbit, a short time after it was indicated in the interior of the tibia by producing a precipitate with sulphate of iron. The same experiment I repeated upon a pigeon, and with like results.

During the passage of the currents of fluid through the articular cartilage, nutritive or organizable in character, if any activity still exists in the life seats, the phenomena of nutrition must be the result.

From the microscopic appearance of the cartilage, we observe that from various interstitial changes, the organic cells must retain at least a part of their wonted activity.

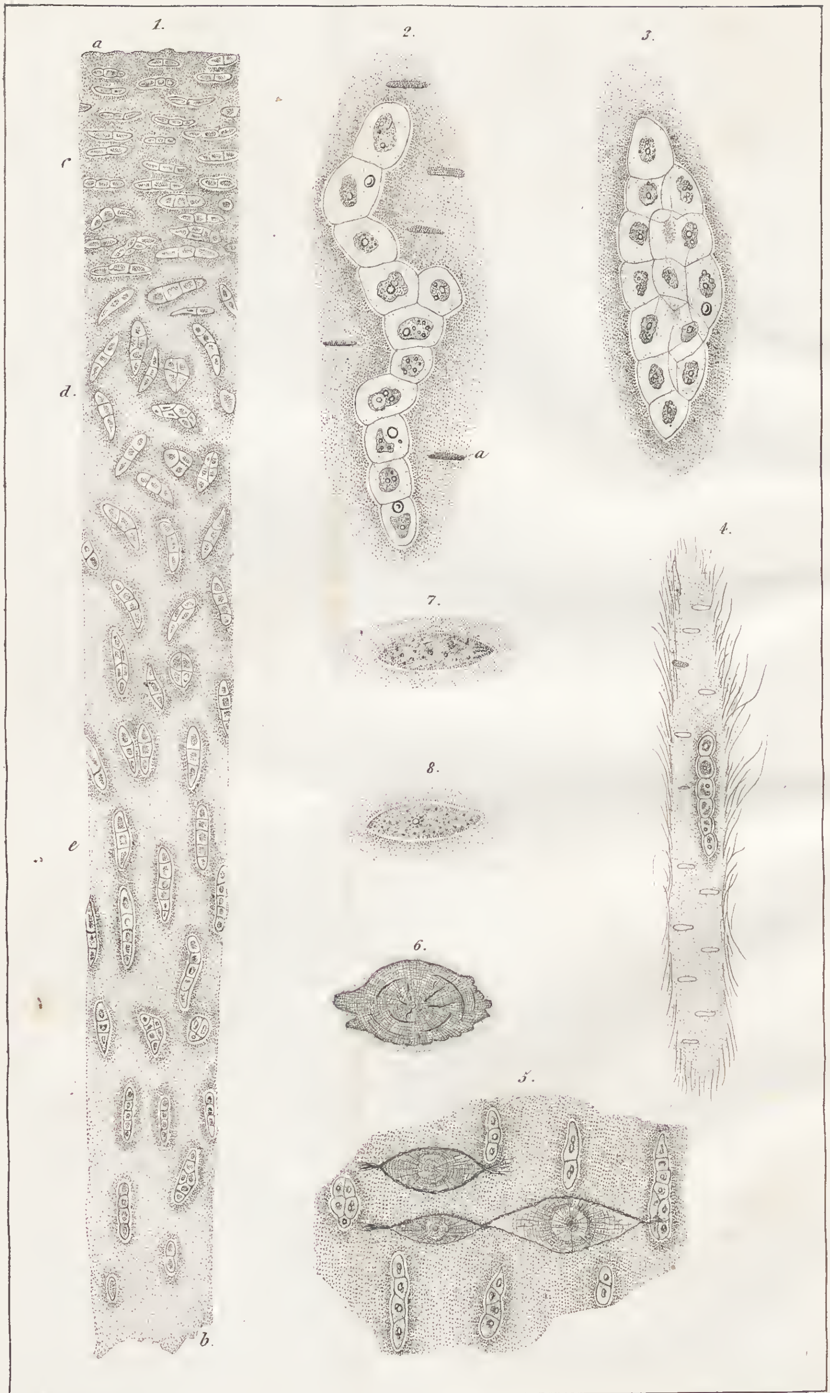
When we consider the amount of rubbing of one articular surface upon another in a movable joint, like that of the knee or hip, under the pressure of the superincumbent mass, from year to year, we cannot help thinking that the wear of the articular cartilages must be more considerable than is generally supposed, although we really perceive but the slightest degree of diminution after a lapse of many years, and even in advanced age, I have frequently noticed hardly any decrease in their thickness. The soft lips of the devotee in a few years will leave a deep impression upon a sacred marble, and I think a walk of some miles per day, through several years, will detach molecules enough from the surface of the articular cartilages, although they are kept constantly lubricated by a substance so well adapted to remove friction, to require a renewal of structure through the process of nutrition.

That such a repair is constantly going on is also rendered probable, by the condition of the more superficial stratum of the articular cartilage, in which are found cells presenting the appearance of having been later formed than those more deeply situated, and this becomes more strikingly the case as we approach the free surface of the cartilage. In the deep part of the cartilage the cell groups are large, the cells are apparently much diminished in organic power by frequent division, and the intercellular matrix is abundant, all betokening an earlier formation than the part lying more superficial to it, in which latter the cells are apparently in the progress of subdivision and formation of groups, and the matrix in comparatively small quantity, like in early cartilage. And then the occasional appearance of the development of new cells in the more superficial cartilage, will still favour the idea of an interstitial nutrition, which though slow, is sufficient to compensate for the wear of the cartilage.

Pathological Conditions of the Articular Cartilages.—As the articular cartilage contains no blood-vessels, so it is not liable to inflammation; but we frequently find cases in which there is an appearance of ulceration or corrosion of the surface of less or greater extent, or it may present numerous minute, disconnected fibres projecting from the surface of the bone, like the pile of velvet, or it may be entirely removed. All these changes may take place from either surface of the articular cartilage. The most prevailing opinion among pathologists of the present day is that these changes are the result of solution generally in purulent matter, and from the observations of Cruveilhier, it appears they are more rapid if the fluid acting upon the cartilage is in a state of putrescence. While the cartilage is bathed in pus, from the catalyso-disorganizing nature of the latter, it may be gradually corroded away from the surface, and from an exosmotic current of the seroid fluid of probably modified pus (scrofulous), filaments may be dissolved out and cell groups detached, or probably disorganized and dissolved out, leaving the remainder of the cartilage in the form of a layer of disconnected filaments, like the pile of velvet, as already alluded to. Should the pus or other catalyso-disorganizing fluid (modified synovia) become putrescent, then must the destruction of the cartilaginous structure be necessarily more rapid, not only from the same action being instituted in the molecules forming the surface of the cartilage, but from imbibition; it will also set up the same action interstitially, and will be aided by the death of the life centres, the cartilage cells, for putrescence is ever deleterious and destructive to cell life. Even the infusorial animalculæ and algous plants, which are generally believed to thrive most in water with putrescent organic matter, with the exception probably of Monads and Vibrios, are absolutely destroyed by it, and it is not until the putrid exhalations cease, that they become developed within the fluid. So long as a lamina of cartilage is left upon the surfaces of the bones of a joint, and the life of the cartilage cells be not destroyed, it is probable there may be the power existing of a very slow regeneration of lost substance, but if the cartilage be entirely removed, as the agents of its formation, the cells, are gone, there can be no restoration. If the bony surfaces be exposed, and pus or other catalyso-disorganizing fluid be present, the destruction of the bones is the result; if the formation of such fluid cease, and what has been formed is removed, and effusion of fibrin from the vessels of the osseous structure takes place from subsequent organization and deposit of osseous salts in the latter, we may have anchylosis, or irregular exostoses. If fibrinous matter be not effused, from the movement of one bony surface upon the other, the excited vessels of the osseous structure may deposit a lamina upon the rubbing surface as hard as dentine, and which from continued friction becomes highly polished.

In the rupture of an articular cartilage it is said the fragments never unite, which fact was formerly frequently advanced in support of the non-organization of the tissue. Muscular substance, when destroyed by violence, is not restored; a lichen cut into two will not unite at the edges; nor will algous plants unite when divided. The nutrition of the parts continues, as is the case with the fragments of the articular cartilage, but as well almost might the

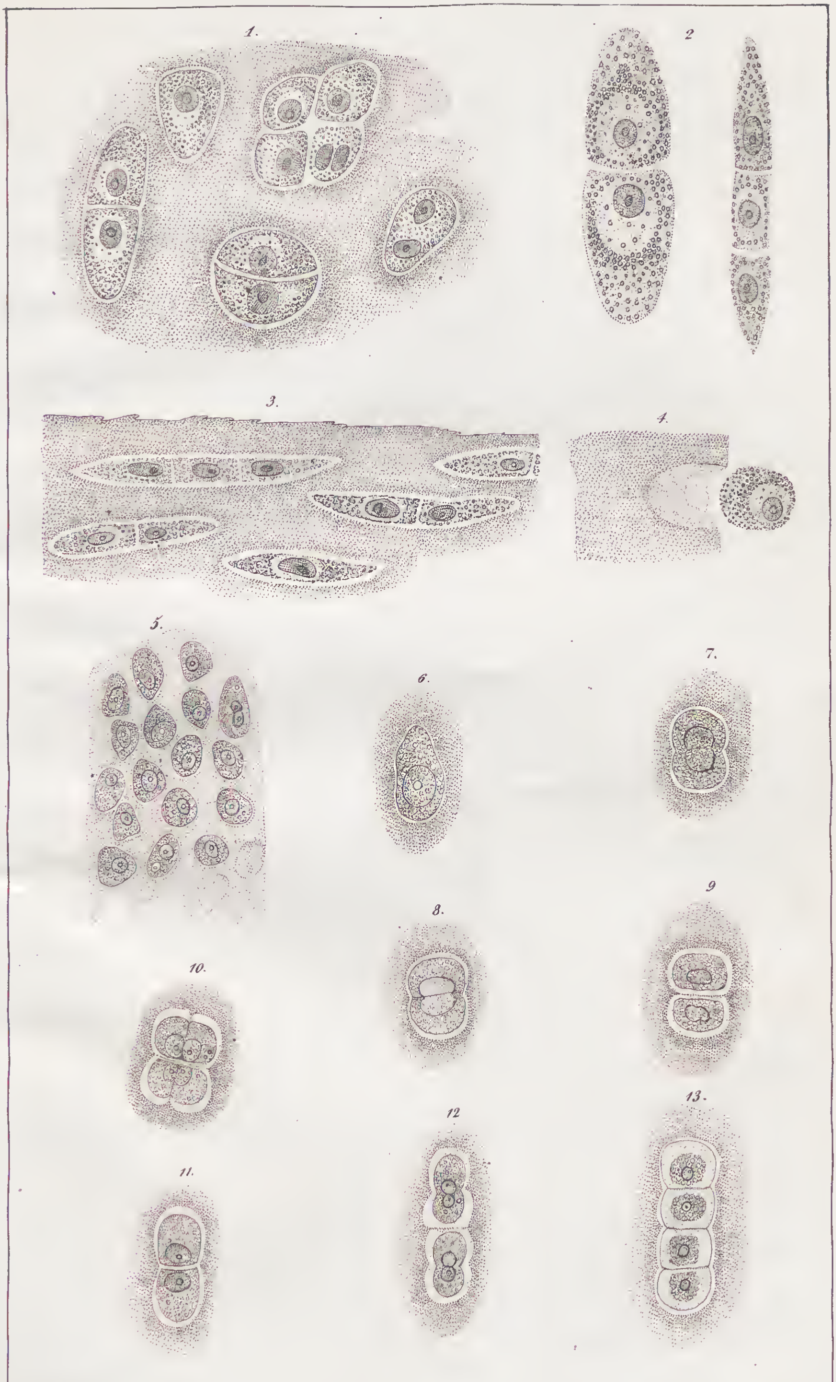
Plate 1.



Joseph Leidy, del.

T. Sinclairs, lith. Phil^a

Plate II



Joseph Leidy, del.

T. Sinclairs, lith. Phil.a

two opposed surfaces of articular cartilage unite in a joint in which there is little motion, as for the two broken edges of one to do so.

When granulations occur upon the surface of an articular cartilage, which is extremely rare, they arise probably from the effusion of fibrin from the circulus vasculosus of the joint, extending upon the surface of the cartilage and agglutinated to it.

REFERENCE TO THE FIGURES.—PLATE I.

Fig. 1 represents a vertical section of the articular cartilage of the head of the os humeri, highly magnified. *a*, free surface of the articular cartilage; *b*, surface of attachment; *c*, superficial stratum of cartilage in which the groups of cells are parallel with the free surface; *d*, stratum in which the course of the cell groups is irregular; *e*, deeper part of the cartilage, exhibiting the general vertical position of the cell groups, and the comparatively large quantity of intercellular substance.

Fig. 2. A cell group from the deeper part of the articular cartilage of the condyles of the os femoris, very highly magnified. It consists of a single row of cells, and does not present so straight a course as usual. In the interior of the cells may be observed the contracted mass of granular contents containing one or two small nuclei, and more or less fat globules. *a*, represents one of the lacunæ, which I have occasionally noticed in the matrix of articular cartilage.

Fig. 3. A group consisting of three rows of cells, from the deep part of the articular cartilage of the head of the os femoris, very highly magnified. In several of the cells, as well as in some of those of the preceding figure, some clear globules will be noticed which have the appearance as if they had escaped from the central granular mass.

Fig. 4 represents a shred of cartilage, torn from the deep part of an articular cartilage from the condyles of the os femoris, prepared as stated in the memoir, highly magnified, and exhibiting particularly the filamentary structure of the cartilage matrix. Some of the peculiar lacunæ are also represented, as this specimen contains them. A vertical group of cells is also figured.

Fig. 5. Vertical section from the deepest part of an articular cartilage of the head of the os femoris, highly magnified, and exhibiting several groups of cartilage cells, and also the transverse section of three of those peculiar fibres of bone, occasionally found pervading the cartilaginous structure, presenting the appearance of their interior structure.

Fig. 6 is a section of one of the bone fibres isolated, exhibiting very well its interior structure.

Fig. 7 represents a cartilage cell, highly magnified, taken from the more superficial part of the articular cartilage of the head of the tibia, and which, I think, is in an early stage of its development.

Fig. 8 represents a cartilage cell, from the same position as that of the preceding figure, and exhibiting an advance in development and the formation of a nucleus.

PLATE II.

Fig. 1. A section of the more superficial part of the articular cartilage of the head of the os humeri, parallel with the surface, very highly magnified and exhibiting the flattened cell groups, apparently of later formation than those more deeply situated.

Fig. 2. Two cell groups from the same position as figure 1; the right hand group, *a*, is viewed upon the surface parallel with that of the articular cartilage, and the other, *b*, is viewed upon the edge or side.

Fig. 3. A vertical section of the free surface cartilage, from the articular cartilage of the head of the os humeri, very highly magnified, and representing the cell groups viewed upon their edges.

Fig. 4 represents the escape of the mass of granular contents, held together by a protoplasmoid envelop, of a cartilage cell in which the wall has apparently become blended with the cartilage matrix, highly magnified, from the surface of the articular cartilage of the head of the os humeri.

Fig. 5. A fragment of surface cartilage from the epiphyso-cartilaginous condyles of the os femoris of a fœtus of six months, highly magnified, and exhibiting the uniform diffusion of the cartilage cells.

Figs. 6, 7, 8, 9, 10, 11, 12, 13, exhibit the progress of development of the cell groups of perfected articular cartilages from the primitive cartilage cells. 6 is from the same fœtus as that of figure 5. The others are from a fœtus at term, a body of six years of age, and an adult.