XXIII. *Researches into the Nature of the Involuntary Muscular Tissue of the Urinary Bladder.*

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During the last few years anatomists have considered the muscular substance of the bladder to be composed of elongated contractile fibre-cells, each with a nucleus in it, which possess free ends, and overlap at their pointed extremities without being united or joined together. This notion of the cell-structure originated with Professor Kölliker; and it has since received very general acceptance*. From the correctness of that opinion I am led to dissent by my researches; and I purpose to show in this communication to the Royal Society, that both the involuntary muscular tissue of the bladder and the voluntary muscular substance in other parts of the human body have a like composition.

In a former paper to the Society (in June 1856)† I made the announcement that the views now brought forward of the muscular structure of the bladder were applicable to the involuntary muscular tissue in general; but as my declaration was received with doubt, I determined to withhold its publication until I had been able to repeat my microscopical observations. Before this time I hoped to have completed the task imposed on myself, but occupation has left me leisure enough to examine thoroughly only the muscular structure of the urinary bladder. As my idea is confirmed by the result of the second examination of that viscus, I submit this paper with greater confidence to the consideration of the Society; and I hope to furnish at a future time additional researches into the nature of the involuntary muscular tissue in other parts of the body.

After a lengthened inquiry, I am emboldened to entertain opinions at variance with the doctrine received at the present day respecting the cell-nature of the muscular substance of the urinary bladder, and to conclude that this material is composed of lengthened fibres with fixed and tendinous end-attachments. According to this view, the muscular wall of the bladder and the voluntary muscles will be formed of similar threads

* Professor Kölliker, in his "Treatise on the Nature of the Involuntary Muscular Tissue in general," says of that in the urinary bladder, "Die Elemente der Muskeln der Blase sind überall die bekannten Faserzellen. In den gelbröthlichen Bündeln, die den Detrusor und Sphincter vesicæ, sowie die schiefen Fasern zusammensetzen, sind dieselben äusserst zierlich spindelförmig und oft wellenförmig auslaufend 0·05—0·07‴ lang, 0·002—0·004‴ breit, mit charakteristischen Kernen von 0·006—0·009‴ Länge."—Zeitschrift für Wissenschaftliche Zoologie, Erst. Band, S. 64. Leipz. 1848.

† See the Abstract in the 'Proceedings' of the Royal Society, vol. viii. p. 212.

or fibres. This resemblance between the two can be best demonstrated by considering the arrangement of the fibres when in mass, the characters of the same when separate, together with the length, end-attachments, and the structure of the component fibres in each kind of muscular substance.

Arrangement of the Muscular Fibres.

In both kinds of muscular tissue (voluntary and involuntary) the fibres are arranged after the same plan.

In the voluntary muscles the bundles of fibres communicate freely with each other, producing a net-like arrangement with meshes, as in Plate XXVI. fig. 2, which represents this plexiform condition in the sartorius muscle of the thigh. This interweaving of the fibres of contiguous bundles existed in all the muscles submitted to examination, and muscles varying in length, breadth, and thickness were designedly selected for comparison.

In the involuntary muscular layer of the bladder the fibres form fasciculi with an angular outline on a cross section, and are surrounded each by a strong fibrous sheath, as in the voluntary muscle. All fibres in the same stratum have the same general direction, either circular or longitudinal, and those of contiguous bundles intercommunicate often, as in Plate XXVI. fig. 1, and give rise to a web with meshes. Not only are the adjacent fasciculi of the same stratum united in the manner specified, but the different strata in the wall of the bladder are joined at innumerable points,—the longitudinal fibres of one layer becoming transverse in another*. The interchanging bands unite in one compact whole the vesical strata; and the same must be cut through before the more superficial can be detached from a deeper muscular layer. The meshes produced by the interweaving of the fibres are smaller than in the voluntary muscle, and those in the deeper parts are closer or finer than the corresponding intervals in the superficial layer. In consequence of this intimate interchange amongst the bundles, a fibre cannot be detached so readily or for so great a distance in the involuntary, as in the voluntary muscular tissue.

Each bundle of fibres of the bladder is marked at short intervals by a tendinous intersection more or less complete, as is the rectus abdominis muscle of the human body. See Plate XXVI. fig. 1, which represents some of the superficial tendinous points dissected out. These small tendons are best recognized in a contracted viscus with rather red fibres; and though they are present throughout the whole muscular substance, they escape detection by the naked eye in the deeper layers in consequence of the general paleness of the texture. In some of the muscular fasciculi the tendons exist only on the surface, involving a few of the fleshy fibres of a fasciculus; whilst in other bundles, and at other spots of the same bundle, they extend through the whole thickness. Where the larger bundles of fibres communicate, there is usually a tendon to be found.

The tendinous points may be placed at tolerably regular or at different distances from

* Transactions of the Royal Medico-Chirurgical Society for 1856, vol. xxxix. p. 328.

each other, the closeness varying from $\frac{1}{10}$th to $\frac{1}{2}$ an inch. When a fasciculus is free for some distance from the usual communicating bundles, the tendons are about $\frac{1}{4}$th of an inch apart. In length they average $\frac{1}{12}$th of an inch (varying from $\frac{1}{20}$th to $\frac{1}{10}$th); and their breadth, which is not quite so great as that of the bundles of fibres bearing them, ranges, according to the difference in size of the bundles, from $\frac{1}{20}$th to $\frac{1}{10}$th of an inch.

On inspection with the naked eye or with a low magnifying power, the tendons may be seen to be formed of white threads, which project unequal distances amongst the fleshy fibres, each receiving a certain number of the fibres, and do not therefore give a defined transverse line across the muscular fasciculus. Under a low power of the microscope, the fleshy fibres, when traced onwards, may be observed to advance into the tendinous mass, and, becoming smaller and fewer in number, to leave a spot where only the common fibrous texture serves as the bond of union between the fleshy bundles entering the tendon at opposite ends. Commonly, however, some fleshy fibres will be seen extending all along the object under examination, in consequence of their reaching different distances in the tendon. How the muscular is connected with the fibrous tissue will be subsequently described.

The tendons above noticed resemble those in the voluntary rectus abdominis muscle in their structure, though, from being placed at unequal distances on the fasciculi of the fibres, they do not form a transverse band as in that muscle; and they are also like them in their use, serving as fixed points for the contracting fleshy fibres.

Similar tendinous points amongst the fleshy bundles of the œsophagus were described in my paper of 1856: these reach entirely or only partly through the bundles of fibres, as in the bladder; they measure in length $\frac{1}{20}$th to $\frac{1}{10}$th of an inch, but in width only about $\frac{1}{30}$th of an inch; and they are distant $\frac{1}{2}$ to $1\frac{1}{2}$ inch from each other. In these both the voluntary and the involuntary fibres of the gullet are collected.

Characters of the Muscular Fibres.

When some fibres of a fasciculus of the bladder have been freed from the surrounding sheath and separated carefully from the rest, they will present the under-mentioned characters with an object-glass of $\frac{1}{8}$th of an inch focus.

Form.—The fibres are slender rounded strings, like the fibres of the voluntary muscle, and present at intervals corpuscles or nucleus-like bodies. If the object under examination is but little disturbed in the attempts to detach it with needles, the pale fibres will appear generally of uniform width. With transmitted light the surface is distinctly granulous or longitudinally striated, and without a dark limiting border. On a cross fracture the end is either solid and dotted, or jagged with separate points, as in a fibre of the voluntary muscle under similar conditions. Not uncommonly many of the fibres under inspection are contracted here and there, and wavy at the narrowed part, as in Plate XXVI. fig. 3 *a*; so that, supposing a fibre to be broken into pieces, the fragments would produce objects with pointed ends and nucleus-like bodies (fig. 3 *b*), resembling

the muscular fibre-cells of Professor KÖLLIKER. When a fibre is contracted, it is like a string of beads in its outline.

Variations in the characters above given may be produced by the manipulation employed in the preparation of the microscopic object: thus if the piece of glass covering the object is pressed down too much, the fibres will be easily flattened in consequence of their great softness. Should a fibre be broken across, it may be bent or twisted, or may differ in width at intervals, narrow wavy parts alternating with larger; or it may be shortened with slightly waved edges and transverse darkened lines; and its free end or ends may be pointed and round, or flattened and irregular like the end of a broken piece of string.

Size.—The fibres vary greatly in diameter in the two kinds of muscular substance.

In the voluntary orbicularis oris muscle of the human body, the smallest fibres measure $\frac{1}{2333}$rd, and the largest $\frac{1}{700}$th of an inch across; and three other sizes can be recognized between those extremes.

In the involuntary fibres of the bladder the smallest measure $\frac{1}{7000}$th, and the largest $\frac{1}{3500}$th of an inch in diameter, whilst the average width is $\frac{1}{5000}$th of an inch. Most preservative fluids diminish the width of the fibres.

Corpuscles.—Elongated granular bodies exist in all muscular tissue; and in the involuntary muscle, as in the bladder for instance, they have been described by Professor KÖLLIKER as the nuclei (Stäbchenförmige Kerne) of his so-called muscular fibre-cells*.

On the addition of acetic acid to voluntary muscle, two kinds of corpuscles, the one oval, the other fusiform, come into sight†. The oval kind, fewest in number, are very pale, with fine granular contents: they are situate within the sarcolemma of the fibres, and flow therefrom with the disintegrated mass on the action of caustic potass; they measure about $\frac{1}{1400}$th of an inch in length, and $\frac{1}{4666}$th in breadth. The fusiform bodies are commonly pointed at each end, and have a yellowish-green colour, with coarse granular contents and a very dark outline, whilst from one or both points a line of fine granules extends for a short distance. In width they vary from $\frac{1}{20,000}$th to $\frac{1}{14,000}$th of an inch, and in length from $\frac{1}{1400}$th to $\frac{1}{700}$th of an inch. They have a linear arrangement along the fibres, and are at variable distances from each other. Oftentimes they are twisted or subdivided.

Usually only one kind of corpuscle, that corresponding with the fusiform of the voluntary muscle, can be recognized in the bladder; but occasionally others, answering to the oval form above described both in their characters and position, will be observed.

The fusiform corpuscles of the muscular substance of the bladder (the rod-shaped

* "Zweitens besizt jede Faserzelle ohne irgend eine Ausnahme einen blassen, in vielen Fällen erst nach Essigsäurezusatz sichtbaren oder wenigstens deutlicher hervortretenden, seltener durch die Säure erblassenden Kern, dessen Grösse und Gestalt sehr eigenthümlich und bezeichnend sind."—Zeitschrift für Wissenschaftliche Zoologie, 1848.

† Reference was made to these in my former paper to the Royal Society.

nuclei of cells of Professor KÖLLIKER) should be examined without acetic acid, or with only a very weak mixture of it and water, as when the acid is strong it destroys the characters of the object under the microscope*. These bodies (Plate XXVII. fig. 4) have the same general form, position on the fibres, and appearance as the corresponding bodies in voluntary muscle, and from each pointed end a faint line of granules may be often traced if weak acid has been used; but their contents are more coarsely granular, and they are somewhat larger and better marked, measuring across from $\frac{1}{14,000}$th to $\frac{1}{4666}$th of an inch, and along from $\frac{1}{1400}$th to $\frac{1}{466}$th of an inch.

The number of the corpuscles on a single involuntary fibre of the bladder will depend on the length of the fibre, and their distance apart is greater than in the voluntary muscle. There is not any bulging of the fibre opposite the seat of the granular bodies (see Plate XXVII. fig. 4 *a*). On account of the softness of the muscular fibres and their frequent interweaving, a single fibre can be separated far enough from its fellows to show more than one corpuscle on it only rarely, and with considerable difficulty. With care, however, I have succeeded several times in detaching a piece of a fibre long enough to have two corpuscles, but only once, as in fig. 4 *a*, a fragment of a length sufficient to possess three corpuscles.

The distance of the corpuscles from one another varies in the same fibre, as well as in different fibres. In the fibre with three large corpuscles (fig. 4 *a*), the middle one is $\frac{1}{233}$rd of an inch from one corpuscle, and $\frac{1}{350}$th of an inch from the other. In five other fibres, each with two large corpuscles, of which measurements were taken, in no two was the interval the same, for it varied from $\frac{1}{280}$th to $\frac{1}{93}$rd of an inch, but the average was $\frac{1}{215}$th of an inch.

Some small and imperfect corpuscles, as in fig. 4 *a*, are often seen between the larger and more complete bodies; and occasionally two larger ones are found near together, as if one was cleft in two.

The measurements above given of the distance of the corpuscles from each other, were made on the fibres of a bladder that was very much contracted, of which fig. 1, Plate XXVI. is a representation drawn of the natural size; and it is therefore to be inferred that the distance would be increased in fibres in an uncontracted state, or lengthened in the distended condition of that viscus. Possibly, too, my seeing two and three corpuscles on a fibre may be due to the approximation of those bodies by the shortening of the intercorpuscular spaces in the contracted fibres. In this same small, but very healthy-looking and muscular bladder, some of the fibres presented a coarse granulous appearance, as in fig. 5, Plate XXVII., either through the whole length of the field of the microscope, or only at intervals: this condition was very like the granulous state often seen in voluntary muscular fibre.

* Little knowledge of these bodies or of the fibres can be obtained by adding acid to a mass of the muscular substance, for the acid takes away all indication of the separateness of the fibres, and allows underlying corpuscles to appear through the superficial and transparent tissue.

Length of the Muscular Fibres.

Actual measurement under the microscope of an entire fibre from the wall of the bladder has been found to be impossible, in consequence of its frequent interweavings with its fellows rendering it inseparable. The length will correspond, it is to be supposed, with the distance between two of the tendinous points into which the fibres are gathered, just as is the case in the voluntary rectus abdominis muscle. Thus the length would vary from $\frac{1}{10}$th to $\frac{1}{2}$ an inch, as the intervals between the tendons, in the greater number of the fibres; whilst in others it may extend over one tendon, as do some fibres before they reach their point of insertion. Considering the length to be determined by the tendinous intersections, it must be borne in mind that this will be greatly influenced by the contracted or relaxed state of the bladder.

By parity of reasoning, the length of the fibres of the œsophagus, where like tendinous points exist, may be estimated.

End-attachment of the Fibres.

The fibres of both the voluntary muscular tissue and the involuntary muscular substance of the bladder have similar end-attachments, by means of fibrous tissue or tendon, as before said.

A voluntary fibre, when about to end in tendon, is surrounded by fibrous tissue, and soon afterwards its component threads or fibrils may be seen to be collected into bundles of varying length and size, which separate slightly as they are continued onwards, like the roots of a tree entering the soil. Each bundle of fibrils is invested with a separate sheath of fibrous tissue, and the aggregate of all the sheaths forms the little tendinous band which is prolonged from each fibre to make up the common tendon of insertion. It appears as if each fibril or thread in the bundle possessed its proper tendinous appendage. The muscular bundles gradually cease to be distinguishable amongst the fibrous tissue; but the central reach further than the circumferential, so that a fibre may appear to have a pointed ending if the surrounding pieces have been broken off in the preparation of the microscopic object. In what way the fibrous tissue is united with the muscular fibre I have not been able to ascertain.

The involuntary fibres of the bladder end in tendinous tissue, like the fibres of the voluntary muscle; but, from their minuteness and softness, I have experienced great difficulty in isolating one, about to cease, from its fellows. Supposing the end of a fibre to be separated, it will be found to terminate as in the voluntary muscle: viz. fibrous tissue is arranged around it, like the long hairs in a horse's tail, whilst further on the fibre appears to divide into pieces, each having its appertaining sheath of fibrous tissue; and lastly, the muscular tissue ceases to be discernible in the fibrous band connecting it with the common tendon (see Plate XXVII. fig. 8). Examination of the fibres entering a tendinous mass does not afford so satisfactory a view of the disposition of the terminal parts as in the case of a detached fibre; but even then they can be observed to divide,

and diminishing in size, with oftentimes wavy ends, gradually to cease amongst the surrounding fibrous tissue, as in fig. 7 of the same Plate.

Structure of the Muscular Fibres.

The characters of the fibres of the bladder above detailed do not lend support to the doctrine of the cell-structure, as explained by Professor KÖLLIKER, but rather lead to the supposition that in construction, as in other respects, the two kinds of muscular tissue have something in common; and after careful examination I am induced to believe that the ultimate composition of the two is not dissimilar. To me the fibres seem to be made up of very minute threads—the ultimate fibrils—as in the voluntary muscle. Indications of this composition are manifested by longitudinal marking, both with and without the action of dilute nitric acid*, and by the separation of the component parts when a fibre is about to end in its tendon, as before described. It is not possible to detach at pleasure one of the ultimate fibrils making up a fibre, as in the voluntary muscular tissue, and possibly from some difference in their uniting medium; but partial accidental separation of them in small bundles, about $\frac{1}{14,000}$th of an inch wide, is not very unfrequent.

I have not succeeded in distinguishing any sheath or sarcolemma to the fibres of the bladder; but by the action of dilute nitric acid the fibres present oftentimes a rough and uneven appearance, as if some encasing material was partly removed.

There seems to be also a further resemblance in structure between the involuntary and the voluntary muscle.

In the voluntary muscular fibre the ultimate fibril is composed, as is well known, of small elongated dark pieces—the sarcous elements, which are united by a transparent material, and give rise by their arrangement to the transverse markings or striæ of the fibre.

On viewing a clean and separate fibre of the bladder with a magnifying power of 600 diameters, it may sometimes appear fibrillated, as in Plate XXVII. fig. 4 *a*, but at other times a fibre will have a granular or dotted surface; just as there may be a difference in the surface-marking of the voluntary fibre, the longitudinal striation being most conspicuous in one specimen and the transverse marking in another specimen. In the large and somewhat flattened fibres, the dark spots, though of small size, are lengthened rather than rounded, and have a linear arrangement in a clear matrix (see fig. 6), though only a small portion of the line of dots will be in focus at the same time, in consequence of the high magnifying power employed. These dots seem to me to indicate the existence of small opake masses—sarcous elements of the involuntary muscular tissue of the bladder, which are the representatives of the sarcous elements of the

* Dilute nitric acid, 20 per cent. strong, has been recommended as suitable for showing the cell-structure of the involuntary muscular substance; but if the microscopist desires to see fibres as they are here described, he must refrain from using that mixture. By the action of the acid the fibres are softened so that they will tear readily in any direction, and are deprived of the tendons attaching their ends.

voluntary fibre. By their arrangement they occasion the granular appearance of the surface under a low magnifying power*.

In the involuntary muscular tissue now described, as well as in the voluntary fibre, the ultimate fibrils will be composed, then, of similar minute particles or "sarcous elements;" but these are so arranged as to produce transverse striæ in the fibre of voluntary muscle, and a dotted condition in the fibre of the involuntary muscle of the bladder.

Explanation of the Plates.

PLATE XXVI.

Fig. 1. This drawing shows the back of the human bladder with the prostate and seminal appendages, together with the urinary canals. The bladder was very fleshy and much contracted, and is here depicted of the natural size. The greater part of the drawing is in outline; but a portion on one side (about the middle) is finished to display the intercommunications of the fleshy bundles, and the tendinous intersections on those bundles for the insertion of the muscular fibres.

Fig. 2. Represents, once enlarged, a fasciculus of fibres from the sartorius muscle of the thigh. Two of the secondary bundles have been unravelled to show the interweaving between smaller contiguous sets of fibres, as in the involuntary muscle; and with greater care a more minute separation might be made. It serves to demonstrate that the muscle is a web-like mass, instead of a collection of long parallel fibres which are fixed only at the extremities of the muscle.

Fig. 3. The figure marked by *a* is copied from a bundle of muscular fibres of the bladder which had been immersed in dilute nitric acid, after the manner recommended to bring into view the cell-structure of the tissue. Bulgings alternate with narrowed and twisted parts on the fibres,—a condition which is not uncommon. Granular masses, some being evidently the remains of corpuscles, are seen here and there.

The letter *b* points to the second figure, exemplifying how fragments of such fibres would resemble the cells of Professor Kölliker, by being wide at the middle, pointed at the ends, and possessing a corpuscle or nucleus. These two fragments, and others like them, were in another part of the field of the microscope.

* Mr. Bowman seems to have thought it probable that similarity of structure might exist in the two kinds of muscle. He says, "Occasionally these granules are arranged in a linear series for some distance. This condition is probably an approximation towards the structure of the striped fibre, for I have observed the granules to be about the size of the sarcous elements of the voluntary muscles above described." —Cyclop. of Anat. and Physiol., article "Muscle and Muscular Action."

PLATE XXVII.

Fig. 4. The chief characters of the involuntary fibres of the bladder have been here portrayed, viz. the inextricable interlacement, the striated appearance of the surface, the corpuscles, and the slender form with nearly uniform width. The fibre referred to by the letter *a* is furnished with three large corpuscles, and with one small, apparently imperfect body.

Fig. 5. A granular state of the involuntary fibres is here indicated. A similar condition may be seen more frequently in voluntary muscular fibres. It has not the appearance of fatty degeneration.

Fig. 6. Parts of two muscular fibres of the bladder, viewed through an object-glass of $\frac{1}{12}$th of an inch focus, are drawn in this figure. The dotted and striated surface-markings, illustrating the structure, are very difficult to recognize and to picture. Oblique is better than direct light for examining the object, as the latter causes the dots to appear like lines. Shading the mirror of the microscope at a distance is sometimes more serviceable for seeing what is described, than either of the before-mentioned modes of illumination.

Fig. 7. Is a representation of the ending of a bundle of the muscular fibres of the bladder in its tendon. Diminishing in size, the fibres penetrate a certain distance without losing their characters; but they then give place to bundles of fibrous tissue, which become undiscernible as distinct bands amongst the mass of surrounding fibrous tissue. A like arrangement exists at the opposite side of the tendon. Corpuscles can be recognized on the fibres near their insertion in the tendon.

Fig. 8. Exhibits the ending of a single fibre of involuntary muscle of the bladder, magnified 600 times. The terminal division of the fibre, and the wavy fibrous tissue encasing the whole, are delineated in detail. The offset of fibrous tissue is prolonged finally to the common tendon of insertion. In the preparation from which the drawing was taken, the solid part of the fibre was not quite so long as it is here made.

Fig. 1.

Fig. 2.

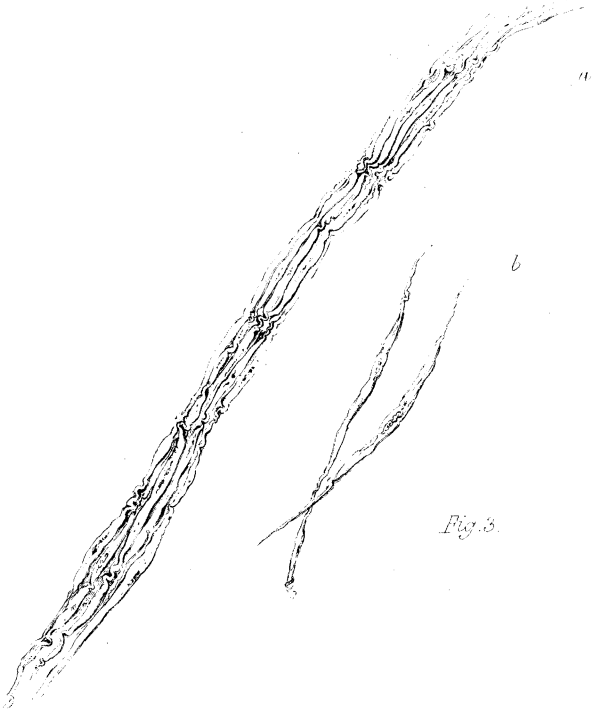
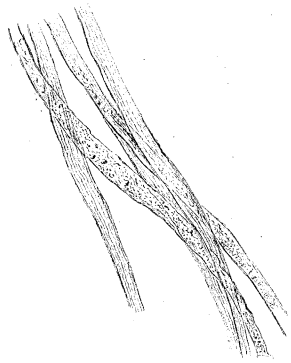


Fig. 3.

Fig. 5.



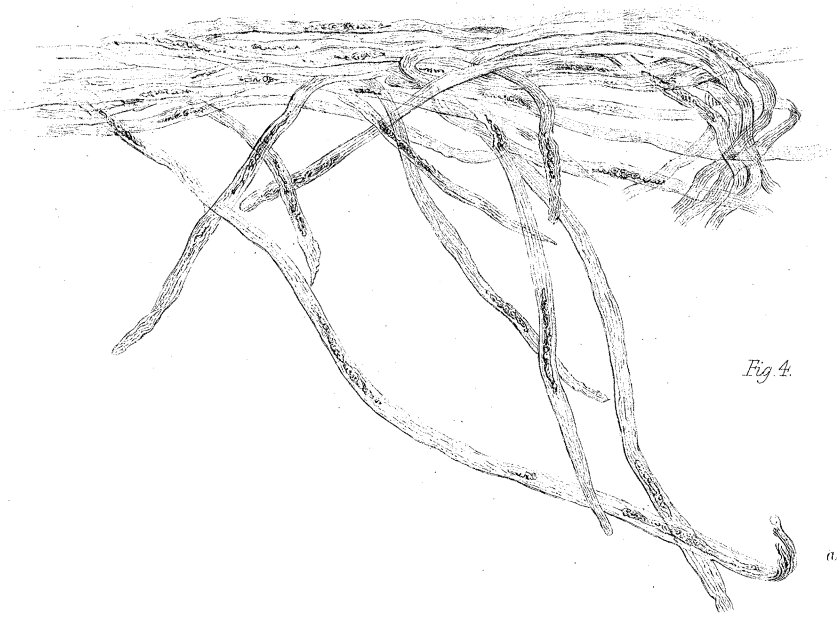


Fig. 4.

a

Fig. 6.

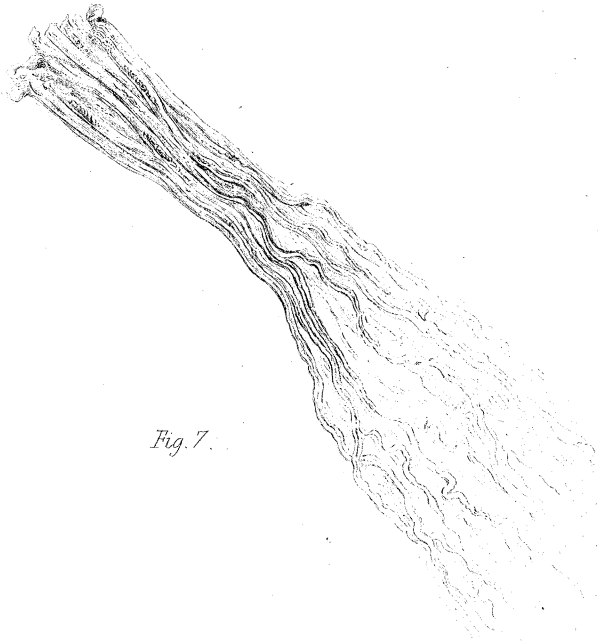


Fig. 7.

Fig. 8.

C.H.Ford del.

Wm.West sculp.