Abstract from notes on the minute structure of the spinal cord / by John B. Trask.

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CONTRIBUTIONS

TO

THE ANATOMY OF THE SPINAL CORD,

By Dr. J. B. TRASK.

SAN FRANCISCO, 1860.

ABSTRACT FROM NOTES

ON THE

Minute Structure of the Spinal Cord.

BY DR. JOHN B. TRASK.

SINCE the days of J. M Meckel, the substance of the brain and spinal cord, with the functions they perform in the animal economy, has engrossed the attention of the anatomist and physiologist. Until within very recent dates, but very little was known of their peculiar structures, and the functions to which they give origin. It may be said with truth, that within the last ten years more positive knowledge has been acquired on this subject, than was developed during the two centuries that preceded this decade.

In 1837, Remak, Purkinje, and Muller, discovered the multipolar cells in the Pons Varolii; ten years after this period, Wagner, in his researches on nerve structure, arrived at the conclusion that the ganglia, or nerves containing them were, afferent in function, and that this particular feature would serve to separate such nerves or centres, from those possessing motor power. This hypothesis soon fell to the ground, and under the searching scrutiny of Kolliker, the theory of those functions set forth by Wagner shown to be entirely baseless; this latter observer demonstrated that the multipolar cells of the former possessed little, if any, of the functions attributed to them.

In 1856, the work of Stilling, on the microscopic anatomy of the Pons Varolii was issued. Having never seen this work, I can judge of its demonstrations only by those who have seen it, and from the remarks of Dr. Todd concerning the powers used by Stilling, it would seem almost impossible that the elements of the nerves should have been seen by him, except the very largest. It is proper here to state that there is possibly an error in Dr. Todd's statements in this particular.

At a still later date, (1859) the thesis of M. Jacubowitsch on experimental physiology was presented to the Academy of Sciences, of Paris. In this paper, the author has entered into the analysis of the elements of nervous

function in the cord, and has demonstrated three orders of cells giving origin to different functions, which are as follows: First, the round or oval cellules; Second, the stellate cells; Third, the fusiform cells. In birds he found the ganglion cells and the cellules of movement largely developed, while those of sensibility are inconsiderable, [relatively?] It was also found that the cellules of movement in these existed in the posterior cornua, and that in this case the elemental arrangement differed from that found in mamifers, for in these latter the afferent elements are largely developed, [exclusively?] in this part of the organ.

The cotemporaneous researches of Lenhossek, do not lead us farther than those of the preceding author, nor so far even, as regards the primordial elemental features of these three orders of nervous function.

This short resume of our positive knowledge on this subject I have thought not inappropriate, as it furnishes at a glance the important features to be considered in future investigation. It is from this point of view in which Jacubowitsch has left us, (as we glean from his official report) that we now take our departure, not that any new elements have been developed under our observations, but to localize those elements in such manner that thay may be more readily found by those commencing these investigations, than can now be done by the publications at our command. Without further preface I will proceed to state the results of my observations in relation to these cellules, and their positional relations to one and the other.

The spinal cord of the sheep was selected for the experiments about to be detailed, for the reason that the animal holds a comparatively recent origin in the animal kingdom, and among quadrupeds possesses a marked delicacy of structure. The rapidity with which softening of its nervous tissues occur after death, being equalled only by that of man.

One of the great obstacles heretofore, has been a want of transparency in sections of nerve tissues, which as a consequence would render very much of the minutiæ of detail obscure or absolutely unresolvable; those objections urged against researches of this character are now removed from the fact that our sections are rendered perfectly transparent by subsequent modifications of Stilling's process, recently introduced by J. L. Clarke, of London. Although the white substance of Schwan is rendered so perfectly transparent as to be imperceptible on the stage, still the outline of the cellules of the cord with their nuclei are so well defined that their characteristics, even to the minute structure of the cell-wall, is easily seen. The learned owe much to the researches of Mr. Clarke in thus enabling them to obtain such superior definition of these minute forms of structure. I would here state in connection with this part of the subject, that the process of Mr. Clarke is far from complete, and that he will find less color, and better definition, in using the *neutral* chromate of potassa, and subsequent to this a very dilute solution of *caustic* alkali; neutralizing the latter with *acetic* acid, and washing with water; the chemical reasons for this will become apparent to him at once on a moment's reflection. I have thus obtained sections perfectly transparent, and ready for mounting in seventeen hours.

I do not propose writing a method of preparation now, for the subject is still a matter of experiment with me as to which is the best method, and we had better wait for a final success or failure, than attempt to expound a process that is immature.

My experiments on the spinal cord of the sheep, were commenced at the first dorsal vertebra, and carried downward to the first lumbar; and then from the place of beginning they were carried upward to the first cervical vertebra. These were the preparatory steps in the experiments, and were conducted in rather a rapid manner, for the purpose of obtaining the position of certain parts which had been previously determined upon for examination, and which were found not to present an entirely uniform phase and position in all parts of the cord intermediate between the points named.

After obtaining through the above means the approximate relations of the parts, I then commenced at the second cervical vertebra, and carried the sections from this to the first dorsal. This portion then is the only part of the cord examined by me with care, and in the present paper I shall attempt to describe but a part of this space, viz.: that included between the upper surface of the second, and the lower surface of the fourth cervical.

The first series of experiments were made upon transverse sections for the purpose of obtaining the relations of position of the nerve elements (?) thus displayed, and those of the columnar and central portions of the organ.

THE CENTRAL CANAL OF THE CORD.

In using the term "canal," in this place, it is done for the purpose of conforming to the use of a word expressing an opening, or cavity in the central portion of the spinal cord. Strictly speaking, we are not justified in its use in this particular, for it has not as yet been shown that this opening is not a closed sac, but to avoid confusion the term is preferred here until further investigation shall develop its true character.

The fact is patent that many of the most eminent anatomists, even of the present epoch, have denied the existence of the central canal of the spinal cord, and Kolliker is among the number of living observers who have taken that position.

On page 655 of the Encyclopedia of Anatomy and Physiology, the same doubt is expressed by Mr. Todd. He says "If such a canal exist, it must be extremely difficult to demonstrate, as I have *never* after numberless examinations, been able to see it. In transverse sections of the spinal cord which have been dried upon glass, there is sometimes an appearance which may be attributed to the presence of a minute canal; but I should be more disposed to ascribe it to the patulous mouth of a blood vessel which had been divided in making the sections, for it is by no means constant even in different regions of the same spinal cord. The situation some have assigned to this supposed canal, is between the gray and white commissures; but Stilling and Wallach place it in the gray matter. It is obvious that an artificial separation of these layers, which is easily effected, and more especially while the preparation is being dried, would give rise to the appearance of a canal upon a trans-

verse section. It may be further stated, that the deepest part of the longitudinal fissure is wider than any other portion of it, and if cut across, might appear like a canal."

Dr. Todd then quotes the observations made by Tiedemann on this subject, in which the latter uses the following language. "The spinal marrow represents a hollow cylinder, the thin walls of which are bent backwards, the posterior part representing a longitudinal opening; for it is hollowed by a groove, *termed the canal of the spinal marrow.*" *

On page 708, Dr. Todd reiterates his remarks on the position assigned it by Stilling and Wallach, and concludes as follows. "The point is one on which I am not prepared to express a decided opinion at present, and which deserves more extended examination."

We have here then the latest competent authorities on both sides, on the existence of the central canal of the cord, and the closing remarks of Dr. Todd most clearly indicate that good reasons were advanced that at least dispel a portion of the doubt which hung over his mind in relation to this subject formerly.

It is clearly evident from the remarks of Dr. Todd and those of Kolliker, that this canal has not been seen by them in the higher mammalia which had arrived at adult age, or, at any rate, it has never appeared sufficiently apparent to those observers except during the periods of fœtal life.

As to the remarks of Tiedemann touching this subject, he clearly regarded the posterior terminus of the anterior median fissure as the point at which the central canal had been located by observers who had preceded him.† In this Tiedeman was undoubtedly correct, but at the same time he was equally wrong so far as regards the central canal or its true position, for this opening in the cord is at a distance posterior to Tiedemann's opening, more than equal to twice the antero-posterior diameter of the canal, and is separated from the position assigned it by those observers, by tissues materially different from the walls of the anterior fissure.

I think there cannot rationally exist a doubt as to the presence of this canal in the spinal cord of the higher ver ebrata. In the sheep, such a canal is present beyond all question, and I make this statement without hesitation, for in *four hundred and thirty sections of the cord of this animal, I have never* (except in a single instance in the upper cervical region) *seen it absent.* I have always found it in any portion of the cord included between the upper cervical and first lumbar vertebra.

These experiments were conducted upon the cord removed from nine animals, and in the sections made from the different specimens, I have invariably met with the same features at identical points of the organ from each

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* Leipsic, 1842. The italics are in the original.

† Recently, (1859) Professor Lenhossek has seen a case where, on opening into the cord, it was found that the pia mater where it descends between the anterior columns, (forming the membrane of the anterior fissure,) had become adherent, and thus formed a canal. Prof. Lenhossek also states that he has never seen the central canal closed [in man] as described by Virchow.

animal. I regard its demonstration as incomparably less difficult, than to bring out the large caudate corpuscles in the commissures.

Every precaution was taken in these experiments to avoid laceration of the tissue of the cord after the sections had been made; *and in no instance was any section allowed to dry on glass, but on the contrary, none of the sections were allowed to become dry on any surface whatever;* if that process had been pursued, laceration of the delicate tissue of the cord could not otherwise than have followed as a consequence of such process, where one five-hundredth was the thickest, and one eight-hundreth of an inch were the thinnest of the sections used.

I have before alluded to the want of transparency in sections of nerve tissue, and the objections urged against the existence of the central canal and other structural portions of the cord, based on the *presumption* that the transparency obtainable in those preparations was insufficient to develop the minute structure abounding there.

So far as regards preparations made by myself, those objections are entirely invalid, for any person with ordinary vision can read through them with ease the finest letter that can be resolved without the aid of a loupe. The letters composing the Lord's Prayer, engraved in the space of one-fourth of an inch, suffer nothing in distinctness with the interposition of these sections between the eye and engraving; I use these engravings as my test for transparency, and reject all specimens which will not transmit light sufficient to enable the eye to thus resolve the letter. This severe test I trust will be sufficient to set aside the question of transparency being unattainable to investigate these structures. In regard to the experiments of Stilling, so far as the location of the central canal is concerned, I think he has placed it in its proper position. I have invariably found it in the place assigned it by him, viz.; in the gray matter, or, more properly speaking, in the central portion of the posterior or gray commissure. While the observations and experiments on the cord by me, fully corroborate his statements in this particular, it is almost impossible to conceive how he should have located this minute opening with so much accuracy, considering the powers Stilling used (10 to 12 diameters, Dr. Todd) in his investigations.*

The central canal of the cord does not appear to be uniform in size or shape at different parts of the organ, but at the same time it holds a great degree of uniformity in the same region of different cords, from animals of the same species; it may therefore be considered symmetrical in form. It could scarcely be expected that its opening would be *perfectly uniform* in all cases in a half inch of the same cord from any one region, for two reasons: it appears to partake of the inequalities of the cord, and would become extinct probably in the lower sacral region, while it is found to enlarge more in proportion in the dorsal swelling, than in the cervical enlargement above it. Another cause of variation in its form is, beyond question, purely mechanical,

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* It appears to me there must be some mistake in these powers as given by Dr. Todd.

and results from our manipulations; when we consider how fragile and delicate is the organ, the extreme tenuity of the sections, and that the canal is formed of a membrane more dense than the columnar and commissural parts surrounding it, and that an almost inappreciable inequality in its sections could not do otherwise than induce a *degree* of distortion, it is not a valid objection to the existence of the canal that it does not always present a perfectly symmetrical outline.

The maximum capacity of the canal seems to be attained in the region of the dorsal enlargement, and is much diminished in the lumbar portions, but is not so small in the latter as in the upper cervical, between the first and second vertebræ; in this region the diminution in size is most particularly marked.

As to the form of the canal in the normal condition, it is somewhat difficult to determine it with absolute accuracy, for the reasons given on a preceding page, viz.: the difference in density of the membrane of the canal and surrounding parts, the distortion arising from corrugation in the hardening process thus casting some doubt on its true shape during life. There is, however, a uniformity in its appearance under the different reagents used on sections from the same region of different cords, and from the features which it presents to my view under the varied conditions in which I have examined it: it may be considered as having the form of an obtuse ellipsoid in the dorsal region, the major axis of which is transverse to the antero-posterior median line. These remarks apply to a general outline only.

To be more specific, it is necessary to state that the form above given of the opening of the canal has a constant modification of the ellipsoid, as follows: antero-posteriorly are two processes formed by reflections of the tissue of the anterior commissure, the posterior and anterior terminations of which are acute; the anterior portions of these processes are the largest, and extend nearly to the peripheral surface of the cord; in fact, they become one of the long processes produced toward the outer surface of the cord from the anterior cornua, but not as given in Stilling's figure as laid down by Dr. Todd, page 706, Ency. Anat. and Phys., Vol. III. On each side of the antero-median line, and lying between these processes, are two rather broad and shallow sulci; the concave surfaces of which are directed toward the anterior columns of the cord. These sulci destroy the regularity of the ellipsoid form of the canal, thus making it an irregular ellipsoid, from the depressions in one of its sides formed by the sulci, and which are lateral to its minor axis.

The membrane of the canal is easily examined in good sections of the cord. It has all the features of a serous tissue, and lines the entire course of the cavity. I am inclined to the opinion that in the normal state, during life, its inner surface is not smooth, but more or less folded, for on a careful examination it is found that the rugæ so very distinctly marked on its inner surface correspond to the process-like prolongations of this membrane thrown out from every part of its border exteriorly. These prolongations of the membrane give to the immediate region about the canal the appearance of a zone of rays entirely encompassing the opening. From the manner in which

this membrane and its rayed portion transmit ligh', and its reactions with chemical reagents, I think there is but little doubt that the rays about the canal and the membrane of the latter are homogeneous in structure and office, but, both chemically and structurally different from either the meningeal, arterial, or nerve tissues. Chemical coloring reagents do not affect it in the same manner as other portions of the cord.

As to the question whether this canal is a bloodvessel, (as Dr. Todd has more than once intimated,) I think there cannot be two opinions when the different effects of the same reagent applied to both are so manifest as is found to be the case on the larger meningeal arteries, and as well also on the smaller arteries of the central portions of the cord. The reactions are as clearly different on the tissues of bloodvessels, and the tissues belonging to the membrane of the canal as an ink mark would be on a surface of paper. It therefore seems difficult to bring the imagination up to that point of tension which would couple the two organs as one, when such differences result on the application of a chemical reagent to both.

From the experiments which I have conducted, I cannot but believe that the membrane of the central canal differs from any other tissue of the cord in a structural, and as a consequence, a functional point of view; if it be identical with any tissue of the cord, it is that of the peripheral portions of the columns; in its reactions it comports itself more closely with those than any other. It is so very different in all particulars from the gray matter that it cannot in any manner be associated with it farther than its regional position. A very interesting feature in the immediate vicinity of the central canal, is the great number of bloodvessels distributed in this region, and which at the same time form so beautiful and striking a contrast with that organ. Their number is variable in sections taken from different portions of the cord. I have never seen less than three, and as many as eight arteries surrounding the canal at the different points at which I have examined the same. They appear more numerous in the cervical and superior dorsal region than below the latter point.

In transverse sections these arteries are easily seen; they have in all respects the same appearance of structure as is to be found in *sections* of the anterior median and lateral vessels of the meninges, and the anterior and posterior arteries which accompany the spinal nerves after their emergence from the cord. These arteries are situated and are most abundant in the substance of the gray commissures, and their distance from the canal is somewhat variable; it is commonly equaled by about the major or minor diameter of the canal as the vessels may be situated in its antero-posterior region or lateral thereto.

These vessels do not maintain a course parallel to the vertical axis of the canal, for many of them in section present an oblique divergence, and from this fact we are led to believe that the tor uosities observable in the vessels of the membranes of the cord are also maintained in the circulatory system of its internal and central structure. We are not, however, left to inferential deductions alone, in regard to the relation of position of the vessels of the

central portion of the cord; in vertical section of the same region the tortuosities inferred from transverse section are seen in greater or less abundance, and the disturbed parallelism of the vessels with the vertical axis is thus proved. It appears to me that the grounds assumed in some quarters that much of the fibrous structure seen in the columns and in the cornua, and commissures, are capillary vessels, must be abandoned, for all the *vessels* in a section of the cord can be *seen*, and it certainly is calling strongly on our faith to ask its extension to that point which would thus convert a colorless and (uncolorable) fibre into a hollow tube conveying a colored fluid, the elements of which can be so easily demonstrated if it exists.

OF THE CORNUA AND THEIR STRUCTURES.

We have to deal now with structure more delicate and complicated than the parts we have just considered.

If special elementary forms of structure are to be taken as our guide as giving origin to the functions of sensation and motion in the nervous centers, it will become necessary for us to so amend our descriptive methods as shall comport with what we see and know to exist in certain parts of these centers. We are taught in our literature that the functions of sensation and motion are found to lie in the different columns into which the cord has been divided, while at the same time it is known that those *columns* do not contain an elemental cell giving origin to either of those functions, but on the other hand, that the columns are made up principally of the cellules of the ganglionic or organic system, (which have not until very recently been supposed to possess motor or sensorial function; this supposition, however, is far from a clearly demonstrated fact at present, for it is impossible to tell how far the fibres of the efferent nerves were affected by the inosculation in the ganglia to which the pole of a galvanic pile was applied; it would be most singular, indeed, that motor action should not follow the application of that stimulus when applied to the superior ganglia of the cervical region, considering the functions of those which so freely inosculate with the ganglionary branches,) and it certainly would seem very irrational to endow a column of the cord with function wherein no elemental form belonging to that function is to be found. Therefore, until the corpuscles of the afferent or efferent systems are shown to exist in either of the *columns* of the cord, the peculiar properties attributed to them by our *literature* must be abandoned.

There are, probably, valid reasons to be advanced which would make the anterior columns an exception to the above rule; (in this particular I wish to be understood as alluding to the large corpuscles beyond and in front of the anterior cornua,) and I am inclined to the belief that the anterior portions of these columns do possess elemental structures giving origin to motor function, and of which we shall speak more particularly in another part of this paper.

The position of the cornua of the cord are so well understood as to require no description here, but their minute structures are not so clearly demonstrated in all particulars in works of general or special anatomy; the

object, therefore, of this part of our subject is to lay down more definitely the position in which the nerve elements are to be found, that they may thus be more easily studied.

The well ascertained fact of the existence of at least three distinct forms of nucleated cells in the spinal cord, and their perfect isolation by well marked and constant boundaries in the higher mamifers, has led the physiologist to investigate closely the particular functions that may emanate from the several groups found within those boundaries. The experiments of Sir Charles Bell on the particular functions of the columnar divisions of the cord, has led subsequent investigators to examine more closely into the parts of the columns from which those functions seemed to have their origin, and to demonstrate the particular elements of structure from which the nerves which were endowed with sensorial or motor properties took their rise.

Among recent observers, none have been more successful in elucidating the existence of the primitive cellules than Jacubowitsch and Lenhossek; the former, more particularly, has carried his investigations toward the ultimate where few have the courage and patience to follow him.

In none of the papers of recent investigators do we find the position of the cellules in their regional relations laid down with that minuteness of accuracy which we should expect from them, and which is so essential a requisite whereby others may be enabled to pursue similar investigations, and also to verify their observations; I have thought it not improper, therefore, to detail those positions in which I have met with the different cellules of authors as found in the spinal cord.

According to our latest investigators the three forms of cells vary specifically in form, function, and, it is highly probable, in structure and composition. To the caudate or stellate cells (the largest) is attributed the function of motion. To the fusiform cells (the smallest?) the function of sensation. To the round or oval belong the organic or ganglionic system. (Jacubowitsch.)

The Anterior Cornua.—These cornua in the cervical region occupy the middle of the antero-lateral portion of the cord, forming the lines of division which separate the anterior from the posterior columns. Like the commissures and posterior cornua, they are composed of the gray matter. The figures in several works on anatomy approximate their appearance sufficiently close for recognition. Stilling's figures approach more closely to their correct appearance than any others, and as Dr. Todd remarks, "they are quite true to nature," [enlarged.]

In the anterior cornua are found the caudate or stellate cells. They lie with the *plane* of their major diameter *parallel* with the *horizontal plane of the cord.* In transverse section of the cord, perfectly parallel with this plane, these stellate corpuscles with their nuclei and nucleoli are brought out most superbly; the *nucleus* and *nucleolus* being then easily seen and *central.* In making sections through this plane of the cord, I have found that the slightest obliquity in the sections so much mars the forms of these cells, that often the caudæ cannot be seen, and the nucleus is either not seen at all, or if

seen, is indistinct and more or less excentric; when obliquely cut they very often present almost the *fac simile* of a round or oval cell of large size, and would under these conditions be placed to the account of the ganglionic system. Such an error as the latter, however, can not occur, when we remember that the *corpuscles* of the ganglionic system do not enter into any of the cornua.

It is not improbable that obliquity of section to the plane of these cells and of the cord also, has been the cause of some of those discrepant statements with which we often meet, in relation to the structure of the anterior cornua and other parts of the cord. If a section of the cord is made through its transverse diameter, so as to include no more than a *single* layer of cells, or two layers at the most, its correct features will then and then only be seen. I am thus specific in this matter, for it can be accomplished, and anything that goes beyond that thickness is objectionable; I propose no more in this matter than I have done, and which I believe I can at any time demonstrate to those capable of judging of the thickness of the cells.

In the second paragraph under this heading, the chorography of the stellate cells is given in the manner there laid down for the double purpose of separating corpuscles that occur in the *anterior columns*, and not belonging to the ganglionic group; also, to obtain more specifically the position of the cells belonging to the posterior cornua. I would now call attention to those corpuscles *of these columns* and their regional position.

It is necessary to remark here that the caudate cells (of motion) are laid down by *observers* as being *confined* to the *anterior cornua*, and by physiological compilers as either in those *cornua* or in the *anterior columns*, or in the *antero-lateral columns*, as the lucidity of the latter may be more or less developed; accordingly, we are quite sure they are somewhere, but the place they hold is not made the more exact by that form of literature. The latest and really the most competent authorities, (Jacubowitsch and Lenhossek,) the former more particularly, includes all those varied forms of motor corpuscles in the *anterior cornua*, and British observers and writers seem to have followed the same trail over which the German observers have subsequently cut out a plainer road.

In addition to the caudate cells of this portion of the gray substance of the cord, there is to be found in the *anterior columns*, and in *front* of the anterior cornua, a group of cells in every respect larger and more developed than those of the cornua; they constitute the quadrangular cells of Jacubowitsch, but they are separate in location from the o her caudate forms before spoken of, and which that observer groups in a single order, location, and function. So far as regards the order to which they belong, and the functions to which they give origin, no question probably can be raised against them, but against their general location an objection I think will hold. I have found these cells situated, as above stated, *between* the anterior termination of the broad cornua and the meninges of the cord, but in no other situation.

From each of the angles of the square of these corpuscles, four large caudæ are produced, and in a very few of them the prolongations were

divided toward the periphery; these corpuscles are all centrically nucleated. Occasionally there is to be seen a corpuscle in this group more or less triangular, which may arise from being cut obliquely; but all the cells of this group have the caudal prolongations much more distinctly marked than any cells found in the anterior cornua.

These cells differ from those of the cornua for the reasons given above, and the following: they are not met with in transverse section; they are situate in the white substance of the anterior columns; they are found only in vertical sections, when the plane of that section is antero-posterior; when the plane of the vertical section is lateral, I have never succeeded in detecting them. Their planes, therefore, are antero-posterior, and their polar axis vertical to the cornual cells, and parallel with the vertical axis of the cord.

From what knowledge we now possess as to the peculiar functions to which the different cellules give origin, there is but little doubt that these corpuscles belong to the efferent system, both from their form and position; but over what particular motor functions they preside, is not so clear from any researches at present made. From the dissimilarity of these corpuscles (in the particulars named) to those of the efferent system, as found in the anterior cornua, it would not seem hazardous to suppose that they may give origin to motor nerves of somewhat special function, as to the nerves of purely involuntary motion.

Taking into consideration the relations of these cells as given above, is there not a probability that they may give origin to the "respiratory system" of Sir Charles Bell, who placed the nerves governing this in the *anterior columns;* and has not his division of the functions of the columns in this particular, more foundation in fact than is awarded to it even by his own countrymen at the present day?

The *general statement*, to the effect that the caudate cellules occur alike in the commissures and the gray matter of the anterior cornua, I thus far have not been able to verify, although I have searched for them most sedulously in the former region. If they have been seen *in situ* by any observer in either of the commissures, I would be glad to know who he is; there are none that I can find who vouch for the fact as stated. It appears to me that this statement has crawled into general use upon a presumption of their presence in this locality in the first instance, based probably upon hypothetical grounds, on account of those cellules being found in such close proximity in the anterior cornua; probably it now obtains credence by that peculiar process of coacervation which pertains to compilers.

I have carefully sought those cells, in very many instances, in the gray commissure, (where they would be most likely to be found if they exist there;) that is to say, in the gray substance extending between and uniting the cornua on both sides; the boundaries of the commissure I include between the central antero-posterior lines of the anterior cornua. In no instance have these cellules been met with by me centric to the bloodvessels which surround the central canal. A few cells having an elongated oval form may at times be seen within the latter points; but to designate them as *caudate cells*, we must leave fact and draw more strongly on the imagination.

To test this question as to the existence of caudate cells in the *commissure*, I took twenty slides of specimens of transverse sections of the cord, all of which were well mounted in balsam, and five sections vertical to the former, made through the region of the commissures, and mounted in the same manner. On the stage of the microscope I obtained the following results from those specimens.

In nine of the transverse sections there was none other than the vesicular mater and the fibres to be seen. In seven others, not more than two of the elongated oval cells presented themselves. In the remaining four slides of this series, more than two, but no more than six of those cells could be demonstrated within the space included. In the slides containing the vertical sections through the region of the commissure, not a trace of one of these cells could be made out. It should be here remarked that the vertical sections have their planes antero-posterior, and that I did not examine vertical sections at right angles to this plane; therefore, the benefit of whatever doubt may arise in this latter case inures to the books. To say the least of the matter, the examination of the twenty-five sections exhibits a paucity of those elongated oval corpuscles, if it does not prove the absence of *caudate* cells entirely.

If the caudate corpuscles do exist in the commissures, it seems most strange that an objective which easily brings out all the other forms of cell, and many of which are far more minute than those, should fail to develop the caudate forms in the commissures, while it so readily resolves them in the cornua of the same specimen. I can conceive of no manner of clearing up this palpable discrepancy, unless it be to *suppose* that the caudate cellules of the commissures (and of which we "read about,") must occupy a different plane than their fellows.

In the long processes thrown out toward the periphery of the cord from the external margins of the anterior cornua, I have not been able as yet to detect other than vesicular matter and fibrillæ. I have examined these processes with much care, and feel satisfied that they are not and do not possess either the properties or structure of bloodvessels, which has been supposed by some to be the case.* To my view they present analagous features to the membranes of the caudate cells. The effect of chemical reagents on these processes is very similar but not identical to that of the same reagent on the walls of those corpuscles, but widely different from its effects on the capillary vessels of the cord.

The Posterior Cornua.—The posterior cornua, like the anterior, are composed of gray substance; their transverse section exhibits nothing remarkable except, perhaps, a lighter tint on section. Sections made through the horizontal plane develop little else than the vesicular matter, except the gelatinous substance toward the outer and posterior parts of the cord. In these cornua are found a series of cells much more delicate than those of the anterior cornua. The cells of this region of the cord are the fusiform elements to which the function of sensation has been allotted. In his thesis on

* Mr. Smee.

Experimental Physiology, (*Comte Rendue*, tome 48, March, 1859, page 502,) M. Jacubowitsch states that these cells are very small, "*les plus petites.*" This does not accord with my observations in regard to them, for in the cervical region I have met with them *equal* in length, but *not* so broad as the caudate cells of the other cornua, and as to their number in this region of the cord, they come fully up to the latter.

I am unable to account for this discrepancy in any other manner than by supposing that this observer founded his remarks on views of the transverse diameter of these cells, at right angles to their poles; that view would, indeed, present them "*plus petites.*" As we are left in the dark entirely as to where he found them so small, it becomes very difficult to verify his statement in this particular.

It is only in vertical sections of the cord that we shall find ourselves able to bring out these corpuscles with anything like distinctness. When thus found they are regular in form, having a centric nucleus and nucleolus, but they *do not* in section, and when *in situ*, present those bifid prolongations which are found attached to them in the improved and borrowed plates. In extremely thin sections, (one seven-hundredth of an inch,) these cells are examined to advantage in their natural positions; we can now discover a colorless fibre projecting from either pole of the cellule, extending in a slightly tortuous line, but vertical to the major axis of the corpuscle. I find it not very difficult to discover bifid cauda attached to the fibrillated prolongations of the cells, when by the use of needles, the compressorium, and other mechanical appliances, and hard work combined, we are thus enabled finally to teaze, squeeze, and grind one of these fibres, until by the force thus used these delicate elements are made to assume phases which it seems to me are entirely foreign to their character.

Such a process for delineating these delicate tissues it appears to me would be analagous to an artist painting infantile beauty, while the innocent was writhing under exquisite torture. As Dr. Funke has remarked, and most justly, too, of the delineations in another department of microscopic research, "they have taken on forms of outline so foreign that it would be difficult to imagine what the figures were intended to represent."

The relative position which the vertical axis of these cellules maintain to the surrounding parts is of some importance, both as regards their anatomical position, and also for facilitating our examinations, for if the cord is examined for them through its horizontal plane, those corpuscles will seldom, if ever, be met with in place.

So far as I have examined the cord, the fusiform cells have been found in the posterior cornua *exclusively*, and in no instance have any been seen by me in the *posterior columns* of the organ. I have not been more successful in finding them *lateral* to these cornua, than in the examinations conducted on the posterior columns.

The relations to the planal position of these corpuscles I find to be as follows: their planes are vertical to those of the caudate cells of the anterior cornua, and they thus become parallel to the major axis of the cord, and also with the quadrate corpuscles before spoken of in the anterior columns.

I have found these corpuscles most abundant in the region in which the posterior roots take their origin,—that is to say, for a short distance *above* and *below* a line cutting the points of emergence of the *posterior roots*, and parallel with the axial lines of the cornua in a horizontal aspect; they are also present in the interspace above and below the emergence of a superior and inferior pair of afferent nerves, but in an inferior numerical proportion.

Up to the present time I have not been able to detect the afferent corpuscles anterior to a line projected laterally and passing through the middle of the central canal. If they exist anterior to this point, they must have an inclination of plane different from that in which they have thus far been met with.

It remains to be demonstrated how far, if at all, the fibres of the afferent cells inosculate with those of the efferent series, and either or both of these with the elements of the ganglionic system. M. Jacubowitsch has made some advances in this particular, (see P. M. and S. Jour., No. XXXII, page 319,) but as yet not entirely demonstrative on this point. His latest researches tend to show that at the junction of the fibres of the nerve elements, whether peripheral or central, inosculation ensues with change of function; should this fact be corroborated by future research, the more rational doctrine of decussation and homology of function must fall to the ground.

The Columns of the Cord.—The division of the cord into the different columns is founded on natural lines formed by the commissures and cornua, centrically. In the columns we meet with element structure differing from that found in either cornua, and in which the round or oval, (the ganglionic cells,) are located. Like the stellate cellules of the anterior cornua, the corpuscles of the columnar portions of the cord can be seen only in transverse sections. The corpuscles of this system are commonly more largely developed toward the peripheral surface of the cord, and they diminish materially in size as the central portions of the cord are approximated: so much so is this the case, that in close proximity to the cornua, the posterior commissure, and between the lateral processes of the anterior cornua, little else than mere vesicles are to be seen.

There seems room for doubt as to whether the ganglionic corpuscles in the cord are not more limited than would at first sight appear, although no really well defined line of demarcation exists between the finer vesicular forms of cells and those so well defined toward the surface of the cord The basis of this doubt is founded on the chemical reactions which are found to ensue in treating this organ, which are *constant* features; the coloration is so manifest at these two portions of the columns that we can scarcely believe the structures alike, nnless we be allowed the latitude of supposing that very much greater delicacy of the walls exists in the cells distant from the periphery, which would in some measure account for the difference of color observed under those reactions.

A point that militates against difference of structure in the cells of the two regions of the same column, is found in the fact, that under amplification and strong light, the cells which refuse deep coloration appear to me to possess a sameness in structure with the larger and more easily resolved forms

toward and adjoining the external surface. It is not impossible that there may be inequality in the thickness of our sections, as between the periphery and central portions, which would in some measure account for this appearance; I have generally found that the central part of the cord did not possess so firm a texture as the circumferential space, after it had been submitted to the hardening process. I must admit such variability in thickness scarcely seems possible, for I can detect no difference in the transparency, and no other difference except the depth of tint.

In many parts of the columns the ganglionic corpuscles present more of the appearance of tesselated epithelium to the eye than anything else to which I can compare them; they may thus be easily recognized from other cells of the nervous center.

These cellules are evidently inclosed in, and possess membranous walls, and are distinctly nucleate; the membrane of the cells presents a well defined outline, clear and distinct, when the *surface plane* of the walls only are brought into focus; their form can then be seen much better than by any other view we can obtain of them; in this focus they present to the eye a semi-opalescent hue, and under two hundred and fifty diameters, an obscurely granulated surface. The nucleus cannot be seen in this focus, *it is below that plane*, but when brought into view, it is found that the membrane of the cell in which it is enclosed is perfectly transparent; when it is in full view, the outline of the corpuscular walls beyond and around it are distinctly seen by a sharp and well defined marginal ring.

The nucleus of the corpuscles are finely delicate; they possess a wall membrane of extreme tenuity, which transmits light much more readily than the walls of the corpuscle when isolated, and with much less coloration; so much so is this the case, that its nucleolus seems more like a minute aperture through which the light passes nearly unobstructed; there is, however, sufficient absorption of the luminous rays to indicate that this, like the nucleus and cell wall, is also membranous.

From the reactions induced in the ray of light on the different structures of these cells, it appears highly probable that the contents of each of its parts are fluid; though that fluid has not been isolated, still the presumption that this is the fact is strong, for it would be difficult to conceive how bodies so transparent, delicate, and membranous, should contain other than a medium of that character; for a substance more consistent than a fluid, it appears to me, would be incompatible with their existence. As the component elements of these corpuscles are still matter of investigation, we will make no further remarks upon the subject for the present.

From such experiments as I have instituted in the investigation of this subject, there seem good reasons for the suggestion of Lister, Turner, and Clarke, that the tissues of the peripheral portions of the columns of the cord, as well also as the neurilemma of the nerves themselves, are both chemically and structurally different. This rule, I believe, will hold good in regard to the ganglionic cells. Thus far I have not been able to impart the colors by Gerlach's process to this order of the nerve elements, while to the afferent

and efferent systems there is not the slightest difficulty in tinging every corpuscle in those systems that can be seen in a section. While the elemental cells of the two latter thus become so clearly defined, it becomes interesting to observe that the fibrillæ with which they are surrounded, resist that process.

The above facts to me seem an insuperable objection to similarity of structure in the cells of the ganglionic system with those of the motor and sensorial elements, and should this feature prove constant in the investigations of others, we shall have gained one more step in our progress of elucidating the occult relations of these very complicated and important structures.