With the compliments of the Author.

MICROSCOPIC STUDIES

ON THE

CENTRAL NERVOUS SYSTEM

OF

Reptiles and Batrachians.

THE SPINAL CORD OF THE FROG—RANA PIPIENS, RANA HALECINA.

BY JOHN J. MASON, M. D.

CHICAGO:
J. J. SPALDING & CO., PRINTERS, 158 CLARK ST.
1880.

Microscopic Studies on the Central Nervous System of Reptiles and Batrachians.

By John J. Mason, M. D.

ARTICLE I.—THE SPINAL CORD OF THE FROG—RANA PIPIENS, RANA HALECINA.

[Reprinted from the Journal of Nervous and Mental Disease, Jan., 1880.]

IT is not intended in these articles to give, in detail, an anatomical description of the nervous system of this class of animals. So far as the anourous group of batrachians is concerned, one could hardly effect such a purpose better than by translating the works of either Reissner * or Stieda,† which together with those of Wyman‡ and Ecker § are in the hands of most comparative anatomists. Only in writing of species, the nervous system of which may not previously have been studied, will a full description be attempted, the main object being to present from time to time facts observed by the author, and regarded by him as supplementary. The form of the spinal cord and especially that of its enlargements; the nuclei of the nerve cells, and variations in their shape, size, etc., in the same individual; the number of ganglionic bodies in the spinal cord, and their relations to the roots of the spinal nerves, and the differences, if any, which may be determined by sex: these, among others, seem to me to be subjects of

*_Der Bau des Centralen Nervensystems der Ungeschwänzten Batrachier._ Dorpat, 1864.

†_Studien ueber das Central Nervensystem der Wirbelthiere._ Leipzig, 1870.

‡_Anatomy of the Nervous System of Rana pipiens._ Washington, 1853.

§_Icones Physiologicæ,_ 1851–59. Liepzig. "Die Anatomie des Frosches des physiologischen Thieres, ist fur den Physiologen, kaum minder wichtig, als die Anatomie des Menschen."

much interest, many of which can be examined remarkably well in cold-blooded animals.

Before describing the method of making preparations which I employ, a few features of the process of Stieda will be noticed. This observer places the entire brains of small animals, first in a solution of 80–90 per cent. alcohol, which has been tinted yellow by iodine. As soon as the piece feels firm to the touch (one to four days according to the size of the specimen) it is placed in a dark yellow solution of bichromate of potash, care being taken to use a large excess of the solution. After a time varying from three weeks to three months, the hardened part is placed in strong ammoniacal carmine, and is removed after from one to five days, placed in alcohol, and after all excess of carmine has been removed, is ready for section.

By this process Stieda has been able to prepare sections in a long unbroken series, of the brains of mice, frogs, etc., saving thereby the risks of several transfers.

My own method is the old one, except in regard to the solutions for hardening. A two per cent. solution of bichromate of potash has given me excellent preparations, also the solution of Clarke, which consists of a solution (1–800) of chromic acid, to each ounce of which a grain of bichromate of potash is added. So far I prefer to stain after cutting. At least two transfers may be avoided by using a siphon tube, to remove alcohol or water, and with the flattened spoons of Seguin, there is but little danger of injuring the sections. After the piece has remained from three to five weeks in the two per cent. bichromate solution, which it is well to renew every two weeks at least, it is placed in Ivanoff's modification of Müller's fluid, which consists of one or more parts of sulphate of soda, until ready for section, when it is transferred to alcohol for a few minutes.

The membranes of the cord ought not to be removed until just before making the sections, or until the part is thoroughly hardened, otherwise deformity will surely result, showing itself in an oval instead of circular central canal. When an unbroken series is not desired, it is better to make sections with the membranes on. After cutting, the sections are stained in Beale's glycerine and water solution of ammoniacal carmine, for which I often substitute the borax carmine of J. W. S. Arnold, after adding to it some ammonia, which rather improves the color. Transparency is effected by oil of cloves, after absolute alcohol has expelled the water, and the mounting is done in Canada balsam dissolved in chloroform. A short piece of copper wire hammered flat at one end and bent at right angles is a good substitute for the steel spoon, as it can be quickly made of any size, and its outline changed by scissors when desired.

The sections of the alligator's spinal cord, which were shown with photo-micrographs at the last annual meeting of the American Neurological Association, measured about 9–10 mm. through the brachial and crural enlargements, and were made from specimens hardened by the same process as that recommended by Seguin* for the human cord.

To prepare isolated nerve-cells, there is perhaps no better method than that employed by Karabanowitsch, viz.: maceration for forty-eight hours in a weak solution of bichromate of potash (2–100) mixed, equal parts, with a (1–100) solution of caustic soda and ammoniacal carmine.

It is possible, however, to make beautiful preparations of the nerve-cells of the frog, by simple agitation, with some teasing, in a drop from a solution of glycerine, water and carmine. Agitation in osmic acid is another common means of isolation, but the preceding methods are generally to be preferred.

The large cellular structures which form such a prominent group in the inferior horns of grey matter are composed of large, sharply defined nuclei, surrounded by protoplasmic masses which, under the action of certain re-agents, look as if they were composed of fibrillæ, which unite in bundles to form what are called the cell processes. The nuclei seem to be but slightly affected by these re-agents, but by prolonged action, seem to be compressed by the surrounding mass. In the cells of medium size the nuclei are rarely if ever changed from the spherical form or circular appearance. These nuclei which contain a distinct nucleolus, are not too numerous to be counted in the frog. For example, in an unbroken series of

**Stricker's Handbook*, p. 646.

twenty-four sections, from the middle of the brachial enlargement of Rana halecina, I counted in both inferior horns 540 large and medium-sized nuclei, and in an unbroken series of twenty-four sections from the middle of the crural enlargement I counted in both horns 390 nuclei. Reissner * estimated the length of the brachial enlargement as standing to that of the crural enlargement in the ratio of 6–10, and this proportion is true of the American species, as would be supposed. It seems fair to conclude therefore, that while the crural enlargement in frogs has a smaller transverse diameter than that of the brachial enlargement, still, by its greater length it contains as many if not more ganglion cells than the latter. It is then, perhaps, the larger of the two swellings and corresponds, as it ought, with the larger size of the posterior extremities.

The preponderance of the lumbar enlargement in birds, and the equality of the two which I have observed in the alligator† and in several species of lizards can undoubtedly be explained, by regarding the amount of grey matter, or possibly the number of nerve-cells, as the surer indication of importance of function in different regions of the cord.

The large crural nerve cells, as well as their nuclei, are larger than those of the brachial region.

This fact I have established by numerous measurements, which may be condensed into the following average diameters for Rana halecina: Brachial nuclei, long diameter, 7; crural nuclei, long diameter, 8; brachial nuclei, short diameter, 6.5; crural nuclei, short diameter, 7.5. The numbers denote divisions of the micrometer eye-piece, each division with the objective used representing .002 mm.

After a thorough comparison of sections from the brachial region of twenty large specimens of Rana pipiens, of which seven were males, I have been unable to detect any difference either in the arrangement, size or structure of the elements, that could reasonably be referred to as explaining the remark-

* Loc. cit.—Length of intumescentia anterior, 6 mm.; that of intumescentia posterior 10 mm.

† See "Transactions of American Neurological Association," in preceding number of the Journal.

able and purely reflex energy displayed by the male frog during the embrace of copulation.* The group of cells with nuclei of medium size, described by me in the *New York Medical Journal*, of December last, is present in the "pars media" of cords from both sexes in three species which I have examined with especial reference to this point.

The distribution of the inferior root fibres in the inferior horns of grey matter, among and to the ganglion cells.

Wyman,† whose memoir appeared at the time Ecker was preparing his *Icones Physiologicæ* for publication, states, page 20: "After the most careful examination, I have not detected any direct connection between these caudate appendages and nerve tubes;" while the latter anatomist prints an illustration after Küpfer ‡ which represents, in a cross section made through the middle of the brachial enlargement, four large nerve cells, with processes running downwards and outwards, as far as the periphery, and two other large cells, from the same group, with processes continuous with the superior (posterior) roots!

Such an exaggerated illustration could never have been made by photography.

Reissner, § ten years later, in a work than which there are few more perfect memoirs, writes: "In regard to the inferior roots, I must premise, that the spinal cord of anourous batrachians, which have been at my disposal, is very little suited for observing the entrance and course of the fibres in the grey substance. * * * * As before stated, a nerve cell may lie near the point of entrance of a bundle, and send one of its processes into the same. (Fig. M.) * * * * The remainder of the nerve root fibres which run upwards or outwards in the grey matter, unite either wholly or in part with large nerve cells."

Stieda, ‖ after contending for the true cell structure of the protoplasmic mass which contains the nucleus, and the struc-

* Goltz.—*Beiträge zur Lehre von den Functionen der Nervencentren des Frosches.* Berlin, 1869.

† Loc. cit.

‡ *Diss. de Medullæ Spinalis Textura in Ranis.* Dorpat, 1854.

§ Loc. cit. pp. 19, 20.

‖ Loc. cit. p. 150, et seq.

tureless state of the axis cylinder, against the views of those who believe in their fibrillary composition, enquires: "How is it now with the connection between nerve-cells and nerve-fibres? * * * * From my observations on fresh as well as on hardened ganglia of the spinal nerves in fishes, amphibia, warm-blooded animals and man, the union is of this nature: the axis cylinder of the nerve fibre is the direct continuation of the cell substance;" and two pages further on, "It seems to me impossible to see such a connection in sections of the brain and spinal cord; it can only be done with the help of isolating methods, as we are taught by the latest observations of Koschewnikoff."* It will be observed that although Stieda has not seen such a connection in a section, he nevertheless considers it as a fact, while Reissner, in 1864, claimed to have seen it; and it was figured by Ecker and Küpfer. Dean † has also a plate showing, in the rabbit, a nerve process joining a nerve-fibre of an anterior root, and passing out as far as the periphery. The frequency with which I have obtained sections from the brachial enlargement of the frog, which show in the clearest manner what becomes of by far the greater part of the inferior root fibres of this region, leads me to give here my manner of procedure.

In the first place, I must assert, contrary to the opinion of Reissner given above, that I know of no other animal so well suited, and for so many reasons, as is the frog, for the study of this point. It is true that the root-fibres in each section are comparatively few; but this seems to me an advantage rather than an impediment, and if more nerve-fibres are desired, it is quite easy to obtain them by making more sections. The supply of frogs is ample; and their spinal cords almost come out of the spinal canal of themselves, so easy is their removal, when the operation is done upon the abdominal side. As the chief cause of failure lies in the division by the razor of the nerve-tube somewhere between the cell and the periphery of the cord, it follows that, *cæteris paribus*, the smaller the diameter of the cord, the greater the chance of success. In

* *Archiv für Microsk. Anat.* Bd. V. 1869.

† J. Dean.—*Microscopic Anatomy of the Lumbar Enlargement of the Spinal Cord.* 1861.

the brachial enlargement, many fibres from the inferior roots enter the cord at right angles, and remain in the same vertical plane while describing a curve laterally, the convexity of which lies towards the inferior median fissure. This is why longitudinal sections are useless for showing this connection; while a series of transverse sections, made in the section cutter, including the roots of the second pair of nerves, will often show, in well stained specimens, the greater portion, if not all, the root fibres passing through the white substance, and, after entering the grey substance, branching outwards among the cells. Most of the fibres lose themselves among the larger external group of cells, while a few are seen to unite with the upper group. In several instances I have traced a connection between cell process and nerve-fibre, with so much certainty, confirming the observation by using a binocular instrument, that I am forced to believe not only in the possibility, but the facility of demonstrating in this way an important fact.

It is always advisable to submit the transparent section to microscopic examination before it is covered, as the weight of the cover is often sufficient to sever fibres. Good objectives, of considerable power, can be used in studying uncovered preparations; and I have succeeded in obtaining satisfactory photographs of some of these.

CONCLUSIONS.

1. The central canal of the spinal cord of frogs is more nearly cylindrical in shape than has been generally supposed. The oval contour is not seen in cross sections below the second pair of nerves, when the membranes are not removed before hardening.

2. The nuclei of the large nerve-cells are more generally oval in form than are those of the smaller cells. I have confirmed this in a few fresh preparations only. It is possible that the re-agents employed have a different effect upon the two classes of nuclei, but it seems more reasonable to conclude that they have a different form anatomically.

3. The nerve-cells of the crural enlargement are as abundant as those of the brachial enlargement, if not more so. Their nuclei are larger, as are also the surrounding masses of protoplasm or cell bodies.

4. No difference in structure can be made out in the upper portion of the cord, corresponding with the sexual function in the male. The long-continued and violent tonic spasm of the anterior extremities, must be explained by local hyperæmia influencing the same structures as those which exist in the female.

5. The relation which is generally believed to exist between the so-called motor-cells and the inferior (anterior) roots, can be demonstrated in the frog more readily than in any other animal.

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MICROSCOPIC STUDIES

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OF

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ARTICLE II.

BY JOHN J. MASON, M. D.

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Microscopic Studies on the Central Nervous System of Reptiles and Batrachians.

By John J. Mason, M. D.

ARTICLE II.—DIAMETERS OF THE NUCLEI OF NERVE CELLS IN THE SPINAL CORD. RANA; EMYS FLORIDANA; TESTUDO POLYPHEMUS.

(*Reprinted from* The Journal of Nervous and Mental Disease, *July*, 1880.)

As early as 1875, while studying the histology of the frog's spinal cord, with special reference to the effect produced by poisons, I was often impressed by what appeared to be an inequality between the size of the nerve-cells in the brachial and those of the crural enlargement. This difference was most striking in longitudinal sections, where a long column of cells was under observation. They appeared to be larger in the crural than in the brachial region. The idea of ascertaining by actual measurement whether the inequality of size were real or apparent, was not then entertained, because it seemed to me that measurements of the body of the cell must be unsatisfactory, owing to the great and constant diversity in its form and in the number, size, and length of its prolongations or processes. Later I was led to measure the nuclei, and last winter published in the January number of this journal the fact that there is a considerable difference in the frog between the two enlargements of the spinal cord, as to the diameters of the cell-nuclei.

Neither Reissner, Stieda, nor any other anatomist, had, up to this time, given in their writings comparative measurements of nuclei taken from these two regions of the cord. Whatever shapes the cell-body may assume, or whatever may be the nature of its substance, the nucleus in these animals presents itself to us always as a sharply-defined, persistent anatomical element, easily prepared for microscopical examination. Readily colored by carmine, in both fresh and hardened specimens, it is especially well adapted for measurement, and its prominence as an object in the microscopic field seems constantly to invite our efforts to determine more about its real nature and function. The writer does not claim to have accomplished much in this direction. The facts, however, which he has brought to light have been established with so much care and precision that he feels warranted in formulating the following law, which he predicts will be found to hold true in all vertebrate animals, viz.:

The nuclei of the cells in the inferior (anterior) horns, in the two enlargements of the spinal cord, have average diameters which are proportional to the muscular power of the corresponding extremities.

The observations which seem to justify the above law are briefly the following:

In the frog, which uses almost exclusively its posterior extremities for locomotion, on land and in water, I find that the average diameters (for Rana halecina) of the cell-nuclei of the crural enlargement exceed, by about $\frac{1}{400}$ of a millimetre, the average diameters (long and short) of the cell-nuclei of the brachial enlargement. The average size of the former stands to that of the latter very nearly in the arithmetical ratio of 7 to 6 divisions of the micrometer eye-piece used with Nachet's objective, No. 5.

In the gopher of Florida, testudo polyphemus (Holbrook), which lives exclusively on land, and digs deep excavations in the earth with its anterior extremities, the latter become quite powerful, and attain a development more than double that of the posterior limbs. The average diameters of the cell-nuclei in the spinal cord of this animal I have found to have a reverse arrangement as to size from that noticed in the frog. The average size of the brachial nuclei stands to that of the crural nuclei in the arithmetical ratio of about 7.5 to 7.

In other words, there was a difference in the diameters of about $\frac{1}{900}$ of a millimetre, the nuclei of the cells of the anterior or brachial enlargement being larger than those of the posterior or crural enlargement.

Again, in the so-called terrapin of the St. John's river, Florida, Emys Floridana (Holbrook), which uses the posterior with much greater effect than the anterior extremities in swimming, and which has correspondingly large hind legs, the arrangement of nuclei as to size is reversed in accordance with the law. The difference in the average diameters I here found to be less than in the nuclei of the gopher; but, whereas in the latter animal the brachial nuclei were found to be larger than the crural nuclei, in the emys the nuclei from the crural enlargement were the larger.

I have also measured these nuclei in the spinal cord of alligators; red-headed lizards, Scincus erythrocephalus (Holbrook); horned toads, Phrynosoma cornutum; and the chameleons of the South, Anolius Carolinensis, without being able to detect constant differences in average diameters between these elements from the two enlargements. Only in the frog and the two species of chelonia referred to, have I found a marked disparity between the brachial and the crural nuclei. This equality of the nuclei in lizards seems, therefore, confirmatory of the law which I hope to have established, for of all the animals above enumerated, frogs and turtles present the greatest inequality in the extremities as to size and especially as to power.

In the alligator and lizards, while the posterior are considerably larger than the anterior extremities, the difference, if there be any, in the power which can be exerted by the two sets of limbs in running or climbing, is inconsiderable when compared with the marked contrast in their functions to be observed in the frog, gopher and emys.

The diameters of the nuclei of the nerve-cells vary in different individuals of the same species, in accordance with the age of the animal. Thus, in a very small but well-developed and active specimen of Rana halecina, I found the average diameters of inferior horn groups from all parts of the cord to be less than those in another specimen of this species, about three times as large. The crural nuclei, however, were found to be larger than the brachial nuclei in both animals. In a young gopher, which had not yet used its anterior limbs for burrowing, the nuclei in general were smaller than those of a full-grown animal, while I could discover no difference in size between the brachial and crural nuclei. It might seem fair to infer, therefore, that the nucleus of a motor cell grows with the muscular substance which it is supposed to innervate. If farther research confirm this inference, a conclusive reason will be furnished for the now common division of nerve-cells into motor and sensitive; for if the nuclei of a definite cell-group are found to increase in size along with the development of muscular power in the related extremities, and to have no such connection with the function of sensation, such nuclei may certainly be regarded as belonging to the motor apparatus.

A word as to the manner of making permanent preparations for counting and measuring nuclei. During the past winter I have tried the method recommended by Stieda * for hardening the brains and cords of small animals, and have found it to be superior to any other that I have yet met with. In transparent carmine-colored sections the nuclei are shown with remarkable distinctness, and can be measured with great ease and accuracy. My custom has been to make an unbroken series of transverse cuts through both the enlargements; mount all the sections, and carefully label all the slides so that all the preparations from the same individual may be kept together by themselves. Longitudinal sections are particularly well adapted for showing a large number of nuclei in the same field.

It is always desirable to measure fresh nuclei when possible. This I have done in the frog and alligator, confirming what was observed in sections. Great care must be taken here to avoid compressing the nucleus between the cover and slide, and for this purpose it is always better to use bits of softened wax to support the cover under its four corners.

When the sections are mounted and the Canada balsam has become sufficiently hard the slide is placed under the No. 5 objective (better to have a movable stage) with micrometer eye-piece † and the group of large cells in one of the inferior horns is readily found. The nuclei of these cells are then

* See this journal for January, 1880.

† Vid. Robin—*Traité du Microscope*, p. 208.

counted, and the eye made familiar with their relative position in the field, in order to avoid measuring the same nucleus twice. The measurements as taken are noted down for this horn, and then the horn of the other side of the section is brought into the field, and so with each section on the slide.* The process is somewhat laborious, but by properly dividing the work it may be gone through with without much fatigue. After all the measurements that are desired are taken, they are added together and the sum is divided by the number of nuclei measured. This gives the average diameter.

EXAMPLE.

MEASUREMENTS OF NUCLEI FROM THE SPINAL CORD OF TESTUDO POLYPHEMUS NO. 1. MAY 15TH, 16TH AND 17TH, 1880.

No. of Nuclei.			Sum of Diameters.	Average Diameters.
224	Brachial	Long Diameters,	1544	6.89
		Short Diameters,	1319	5.87
220	Crural	Long Diameters,	1448	6.58
		Short Diameters,	1198	5.44

The above diameters are in divisions of the micrometer eye-piece with Nachet No. 5—7 divisions being equal to .0175 m.m.

* It is often possible to mount as many as twelve sections on the same slide.

MICROSCOPIC STUDIES ON THE CENTRAL NERVOUS SYSTEM OF REPTILES AND BATRACHIANS

ARTICLE III

DIAMETERS OF THE NUCLEI OF THE LARGE NERVE CELLS IN THE SPINAL CORD (*continued*), ALSO OF THOSE WHICH GIVE ORIGIN TO THE MOTOR FIBRES OF THE CRANIAL NERVES

BY

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NEWPORT, R. I.

[Reprinted from the JOURNAL OF NERVOUS AND MENTAL DISEASE, Vol. viii, No. 1, January, 1881]

WITH THE AUTHOR'S COMPLIMENTS.

THE WRITER DOES NOT MAKE ANY REFERENCE IN THIS ARTICLE TO THE THEORY, WHICH PRETENDS TO DISTINGUISH BETWEEN MOTOR AND SENSORY CELLS, NOR HAS HE EVER ENDORSED SUCH A THEORY, EVEN BY INFERENCE, BUT HAS DISTINCTLY STATED THAT SENSATION HAD NOTHING TO DO WITH HIS SUBJECT.

MICROSCOPIC STUDIES ON THE CENTRAL NERVOUS SYSTEM OF REPTILES AND BATRACHIANS.

By JOHN J. MASON, M. D.,
NEWPORT, R. I.

ARTICLE III.

DIAMETERS OF THE NUCLEI OF THE LARGE NERVE CELLS IN THE SPINAL CORD (*continued*), ALSO OF THOSE WHICH GIVE ORIGIN TO THE MOTOR FIBRES OF THE CRANIAL NERVES.

SINCE writing article II of this series, I have met with nothing which could fairly be regarded as an objection to the law then presented, but have, on the contrary, noted many new facts which tend to strengthen it and widen its application. Nuclei which, by means of the prolongations of their surrounding cell masses, are related to muscles, have been carefully measured throughout the entire nervous system.

Scattered cells, like those found singly or in pairs near the course of the abducens nerve, with those which I have elsewhere described as existing in the meshes of the raphe of the alligator, and certain large cells in lizards, serpents, and turtles which appear to be connected with the acoustic or facial nerves, may all be classed as of doubtful function. Although the diameters of their nuclei may in some cases seem to furnish exceptions to the rule, so long as their anatomical relations remain obscure nothing can be definitely affirmed about them in this connection.

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I would suggest, however, to those who may feel disposed to regard these cells as connected with the sense of hearing, that such a view involves giving to this apparatus, in its central portion, a structure almost identical with one universally admitted to be motor, like, for example, that concerned in raising the lower jaw; whereas in the central structures for vision and olfaction the cells are all very small.

Moreover, these large cells, found in the vicinity of the acoustic nerve in some lizards, turtles and serpents, are not found at all in the frog, while in the alligator their position indicates that they may be related to the motor branch of the fifth pair or possibly to the branch which supplies the depressor muscles of the lower jaw. The eminentia acoustica in the latter animal swarms with uniformly small cells and nuclei which are very probably the sole centres for the acoustic nerve, and in the same relative plane the same numerous groups of small cells can be seen in frogs and some lizards.

During the past summer, through the kindness of Prof. S. F. Baird, of the Smithsonian Institution, quite a number of valuable specimens have been placed at my disposal, among which may be mentioned Heloderma Suspectum, several serpents and one large example of Chelydra Serpentina.

Nuclei of the cells of the inferior (anterior) horns of the caudal, lumbar, dorsal, cervical and upper cervical regions of the spinal cord, in a large number of frogs of three species, two species of emys and two of land turtles, and in several alligators and lizards, including heloderma, have been measured. Of those found in the cervical and lumbar enlargements enough has been written already in the two preceding papers. The preponderance in average size is here in striking accord with that of the power of the related extremities, and has since been repeatedly confirmed in frogs,* especially in longitudinal sections.

The caudal region in turtles and in those lizards which have few and delicate caudal muscles furnishes an interesting fact for consideration. In turtles the cell nuclei gradually diminish in size from before backward, and finally disappear altogether near the posterior portion, where the horns of gray matter present much the same appearance, as to structure, as that of the same parts in the dorsal region.

While in the alligator some of the largest cell nuclei are met with in this part of the cord, in those saurians, heloderma especially, which have comparatively little power in the tail, these elements are reduced gradually in size in the same sense as are those in the turtle. The same gradual transition is well marked in the caudal region of Scincus Erythrocephalus.

Stieda* gives measurements of nerve cells and their nuclei from the various parts of the spinal cord in Testudo Græca and Emys Europæa, agreeing with my own made later, and concludes as follows:

"I guard myself expressly against the supposition that the great differences in size between these three (large, medium-sized, and small) classes of cells are evidences of different physiological importance in these elements. I wish rather to assert that what is found in the spinal cord of the turtle can and must be used to support the contrary view. The fact that in the caudal and dorsal regions no large cells exist, but only medium-sized and small cells, while inferior (motor) roots are given out from these same regions,

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* In the spinal cord of a bat which I have lately examined, the nuclei of the cervical region were found to be far more abundant than those of the lumbar region, and their average diameter somewhat greater. The muscles of the two pair of extremities bear the same sort of relation to each other.

"Ueber den bau des centralen nerven systems der amphibien und reptilien." Axolotl and Schildkröte, Leipzig, 1875, p. 40.

must have great weight against the conclusion that only the large nerve cells are connected with motor fibres." Accepting the passage as it stands I agree with him, but he has not fairly stated the ordinary view. It does not seem to me that "only the large nerve cells are connected with motor fibres," represents fairly the prevailing belief of anatomists and physiologists. That all the large nerve cells are thus connected is more accurately what is thought to be the fact. Of course, no one has ever claimed that the cells of origin of the oculomotorius, for example, were large cells or doubted that they were in connection with the fibres of the third pair of cranial nerves. Nerve cells, therefore, may be small and still be connected with motor nerve filaments. In the dorsal and caudal regions of the spinal cord of turtles the motor cells are small, because the muscles which they innervate are small. At the same time, it may be true that all large cells connect with motor filaments. To me, this is all in favor of ascribing difference in energy to different-sized cells or rather nuclei. The nucleus can be accurately measured, while the body of the cell can not be, and as the former probably constitutes the true cell, it has been preferred as an object of study in my researches.

MEASUREMENTS OF THE DIAMETERS OF THE NUCLEI OF NERVE CELLS WHICH ARE RELATED TO THE MOTOR FIBRES OF THE CRANIAL NERVES.

1. In four species of turtle, viz.: (1) Emys Floridana, (2) Emys Terrapin, (3) Testudo Polyphemus, and (4) Chelydra Serpentina, the following have been found to be the comparative dimensions of these nuclei:

The largest nuclei are found in the cells of the spinal cord and those of the nucleus basilaris of Stieda. Next to these in size are those of the centre for the motor root of the trigeminus, supplying with its fibres the elevator muscles of the lower jaw and next those of the centres of the oculomotorius. This is true of all four species.

In the first three animals weighing about four pounds each, the nuclei for the respective centres were about equal, while differing in size in each individual as stated above. In the Chelydra Serpentina (snapping turtle weighing 24½ pounds) all the motor nuclei were much larger than those of the smaller specimens. The same rule holds true in frogs and alligators. The smaller the animal, the smaller the cell nuclei. I have not seen any mention of this fact in any works on anatomy.

2. The nervous centres of the alligator are especially well fitted for sections, and I have obtained three series of preparations, many hundred in all, showing the nuclei of the cells of origin of all the motor nerves. In this animal, the cell nuclei of the motor root of the trigeminus are found to occupy, as to size, the same middle rank between the nuclei of the oculomotorius and those of the motor roots of the spinal nerves, that they do in the turtle. These nuclei are remarkably large in both the alligator and snapping turtle.

3. In frogs the rule is even more strikingly illustrated than in the animals just mentioned. Anatomists have, as yet, made no centre for the hypoglossus, but it is interesting to note that, the nuclei of the cells forming the "nucleus centralis" of Steida, described and figured also by Reissner (the natural centre for this nerve), have a diameter just between that of the nuclei related to the oculomotorius and those related to the motor root of the trigeminus.

The constant variations in the size of these elements above indicated have been clearly illustrated by photography. By employing exactly the same degree of enlargement—by using the same objective and having the same distance always between the focusing screen and microscope—for all the nuclei of the same animal, a very accurate representation of the actual condition is possible.

These photographs can now be examined at the library of the Academy of Medicine, the New York Hospital library, College of Physicians, Philadelphia, Surgeon-General's office and Smithsonian Institute, Washington, and at some university libraries. The same subjects, with over a hundred others, printed by the Artotype process on plate paper, showing the structure of the central nervous system of all the North American reptiles, will soon be published.

RECAPITULATION OF THE FACTS OBSERVED IN REGARD TO THE SIZE OF THE NUCLEI OF THE NERVE CELLS IN THE SPINAL CORD AND BRAIN OF REPTILES AND FROGS.

I. —FROG.

Diameters in divisions of Nachet's micrometer eye-piece with objective No. 5 :

Spinal cord, brachial enlargement	6.5 x 8.
" crural "	7. x 9.
Centre of motor root of trigeminus.	6. x 6.5
Possible centre of hypoglossus	4.5 x 6.
Centre of oculomotorius	3.5 x 4.5

II.—EMYS FLORIDANA.

Spinal cord, cervical enlargement	6. x 6.5
" lumbar "	6. x 7.
Dorsal region	2. – 4.
Caudal " gradually diminishing	6. – 2.
Centre of motor root of the trigeminus	5. x 5.
Cerebellum, large cells	4. x 5.
Centre of oculomotorius	3.5 x 4.5
Cerebrum	3.5 x 5.
Optic tubercles	3. x 3.5

III.—TESTUDO POLYPHEMUS.

Same as emys, except in spinal cord where the conditions are reversed in the two enlargements.

IV.—ALLIGATOR MISSISSIPIENSIS.

Spinal cord, cervical enlargement	6.5 x 7.5
" lumbar "	6.5 x 7.5
Centre of motor cord of the trigeminus	6. x 7.
" motor portion of the vagus	5.5 x 6.
" oculomotorius	5. x 5.
Large cells of the raphe	7. x 8.
Nuclei of eminentia acoustica	3.5 x 4.5
Sensitive cells of the vagus	3.5 x 4.5
Large cells of the cerebellum	3.5 x 4.5
Cerebrum and corpus striatum	3.5 x 4.5
Optic tubercles	2.5 x 3.

V.—HELODERMA SUSPECTUM.

With the exception of the caudal region of the spinal cord, where much the same scarcity and successive reduction of size of the nuclei exist as in the turtle, the diameters hold the same relation to each other as noted in the alligator. This remark also applies to the nuclei of Scincus Erythrocephalus.

VI.—~~ERYTHROCEPHALUS.~~

The nerve cell nuclei of small specimens are notably smaller than the corresponding nuclei of larger specimens of the same order. This rule only applies to orders, for some of the nuclei of Rana Pipiens, from the spinal cord, measure as much as those of the 24-pound turtle. The nuclei of the small lizards are, as a whole, proportionally larger than those of heloderma or the alligator.

The proposed law, formulated in my last paper, may now read as follows:

The nuclei of the so-called motor cells of the central nervous system have, in the same individual, average diameters, which are proportional to the power developed in the related muscles.

The writer, in conclusion, while admitting the incompleteness of his work, must at least claim to have demonstrated the fact that a hitherto unobserved relation exists between the size of a motor nucleus and that of its peripheral organ, the muscle.