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THESE VOLUMES ARE DEDICATED

TO THE MEN AND WOMEN
OF OUR TIME AND COUNTRY WHO BY WISE AND GENEROUS GIVING
HAVE ENCOURAGED THE SEARCH AFTER TRUTH
IN ALL DEPARTMENTS OF KNOWLEDGE

# INVESTIGATIONS

THE UNIVERSITY OF CHICAGO
FOUNDED BY JOHN D. ROCKEFELLER

# INVESTIGATIONS REPRESENTING THE DEPARTMENTS

## ZOÖLOGY ANATOMY PHYSIOLOGY NEUROLOGY BOTANY PATHOLOGY BACTERIOLOGY

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# THE FINER STRUCTURE OF THE NEURONES IN THE NERVOUS SYSTEM OF THE WHITE RAT

# THE FINER STRUCTURE OF THE NEURONES IN THE NERVOUS SYSTEM OF THE WHITE RAT

Shinkishi Hatai

The two problems which we have to consider are the fundamental structure of the ground-substance of the nerve-cells and the manner in which the axone of one neurone terminates on the dendrites or on the cell-body of another. Many opinions and theories concerning this structure and these relations have been put forth during the last decade, and as a consequence the literature of this subject is already very large. Nevertheless it cannot be said that either of the questions has been definitively solved. With the aid of a new technique we have been able to see some structures and relations not heretofore described, and it is the object of the present paper to interpret and depict these new appearances.

## I. TECHNIQUE

For the present investigation a large number of white rats having body-weights ranging from 5.4 to 185 grams were employed. The material was preserved with Gilson's fluid, Carnoy's mixture, and the mixtures devised by the present writer (1901); as the staining agents, saturated aqueous solution of thionin followed by a 1 per cent aqueous solution of erythrosin; Heidenhain's iron-hæmatoxylin, and Ehrlich's triacid method were used. In applying these several methods the author's directions were strictly followed. In each case, after imbedding in paraffin according to the usual procedure, sections were cut three micra in thickness.

Besides these methods, the present writer tried another method which gave very satisfactory results in the study of the ground substance of the nerve-cells as well as in that of the finer structure of their processes. This method is as follows: As soon as the fresh material was removed from the body, it was put directly into the following solution. The pieces should not be more than 5 mm.$^3$.

1. Acetic-picric-formalin mixture (after the writer, 1901) - - 250 c.c.
2. Acid fuchsin, saturated aqueous solution - - - - - 50 c.c.

After twenty-four hours the pieces were taken from the solution and were teased in glycerin with fine needles. In this teased preparation only the achromatic substance of the nerve-cells and processes stain, while the rest of the cell-substance remains unstained. For this reason it offers us several advantages for the study of the minute structure of the axone and dendrites not possessed by other methods which were employed. Although this preparation gives such satisfactory results, it cannot be preserved permanently, as the color soon fades. To meet this difficulty, the material thus preserved and stained may be imbedded in paraffin after having been carried

through 95 per cent. and 100 per cent. alcohol and xylol. In this case, however, the section must be restained upon the slide. These restained preparations give clearer pictures than those obtained by other methods, and, in addition, show a distinction between the axone and the dendrites. The appearances about to be described were obtained by this method.

## II. THE FINER STRUCTURE OF THE GROUND SUBSTANCE OF THE NERVE-CELLS, ESPECIALLY OF THE SPINAL GANGLION CELLS

The spinal ganglion cells in the white rat present at least two varieties differently characterized; one of the varieties is larger in size and stains faintly with eosin or erythrosin; while the other shows just the opposite characters, that is, the cell-bodies are smaller and stain deeply with these solutions. The present description of the spinal ganglion cells is based on the study of the larger variety which has been regarded by the writer as the fully matured form (1901).

In general, the cell-body shows a circular or a somewhat oblong shape, containing a single nucleus which lies at or near the center of the cell. The nucleus contains a large number of the oxyphile particles of various sizes. These particles are most abundant at the periphery of the nucleus as well as around the nucleolus which lies near its center. These particles hang along the fine filaments of the linin substance which forms a very complicated network in the nucleus (Plate XIII, Fig. 1). By using toluidin blue and eosin, the oxyphile substance and the linin stain red, while the nucleolus stains an intense blue, owing to the accumulation of the basophile substance around the oxyphile substance which forms the nucleolus proper (1901[3]).

The distinction between the oxyphile and the linin substance may be made out by the fact that the latter stains more faintly. The nuclear membrane is distinctly visible, showing a somewhat reddish brown color. The cell-body proper is composed of at least two different substances, as is the case in all other nerve cell-bodies, namely (1) the stainable substance known also as tigroid, Nissl's bodies, chromatophile particles, etc., and (2) non-stainable or ground substance. The stainable substance just mentioned appears to fill up the cell-body, except in two regions, one along the periphery of the cell-body and the other around the nucleus, the regions being known respectively as the peripheral and the inner, clear zones (Lenhossèk, 1895). In these two regions the non-stainable substance alone is visible.

Under a low magnification the cell-body appears as a red homogeneous mass with a bluish tinge in it. A higher magnification of such a cell reveals a large number of minute meshes presenting a reticular arrangement. These meshes, however, are not similar either in shape or in size, but differ very widely according to regions in which they occur. They are formed by very delicate protoplasmic filaments within which minute granules are clearly distinguishable. These granules are known as "neurosomes." The neurosome seems to be a very highly differentiated cytomicrosome and to form the main part of the filament. The neurosome stains much deeper with eosin or erythrosin than ordinary cyto-microsome, and also is much larger than it.

As was pointed out by Held (1897), the neurosome is not only found imbedded within the filament, but appears also in the meshes between the filaments. The neurosomes in the region of the terminal end of the axis cylinder are very much larger than those found in the rest of the neurone (Plate XIII, Fig. 1).

As has already been mentioned, the meshes formed by the filaments are highly variable both in size and in shape. Generally, in the clear zone at the periphery of the cell-body, the meshes are larger and more conspicuous than in the remaining part. In the neighborhood of the axone hillock the meshes are not only much diminished in size, but they are also elongated. Around the nucleus these meshes reach a minimum size. The form of the reticulum at the periphery shows meshes of a somewhat polygonal shape, but in the remaining part of the cell these meshes are elongated, especially around the nucleus and near the axone hillock. These modified meshes present a fibrillar appearance, especially those around the nucleus as well as in the neighborhood of the axone hillock, owing to the alteration which has been described; that is, the elongation of the meshes diminishes the original space contained between the filaments and renders the filaments approximately parallel. In some cases several of these filaments unite together and form very thick strands. These secondary alterations take place throughout the cell-body and around the nucleus, but never occur at the periphery of the cell. Thus, the fibrillar structures as well as the fibrillar network within the cell-body are produced. These fibrils, therefore, are very different from those described by Apàthy and Bethe. According to Golgi (1898) and others, a modified silver-nitrate technique brings out a new structure within the nerve-cells. This structure presents very complicated network around the nucleus, and to this the name "endocellular network" has been given. It seems probable that the endocellular network just mentioned may be one expression of the elongated meshes of the fibrillar substance observed by the writer. Since Golgi's technique does not bring out the very minute structures, the figures obtained by him are only a fragment of the network which we have described. I will take up this point later on and will present the evidence I have for identifying this endocellular network with the structure to be seen within rats' nerve-cells.

Among the neurologists, two different views concerning the structure of the ground substance in the nerve-cells are held: These may be designated as (1) the fibrillar, and (2) the non-fibrillar or reticular. These two appearances in the protoplasm have been brought out by using different techniques. Apàthy (1895) demonstrated the fibrillar structure in the annelid nerve-cells by using gold chloride; Bethe (1897) in the crustacea, killed with nitric acid and stained with toluidin blue; Cox (1898) by osmic acid; Flemming (1895) by his own fixing agent; Dogiel by methylen blue; Becker (1895) by Weigerts' copper and hæmatoxylin stain; Kronthal (1895) by staining freshly crushed and dried specimens with methylen blue, etc., while the reticular structure was obtained by Bütchli, Held, Lenhossèk, Van Gehuchten, Cajal, and others, using either strong alcohol, corrosive sublimate, Gilson's mixture, or Carnoy's solution.

The writer has had the opportunity to study the preparations made after the method of Bethe, Dogiel, and Kronthal, and to compare those with his own preparations from the white rat. In these cases, however, the writer was unable to see any fibrillar structure, such as had been described by those writers, but observed only a reticulum producing pseudo-fibrils. Although the reticular structure of the ground substance seems to be characteristic for young and unmodified nerve-cells, nevertheless in the large multipolar cells it has been altered to such an extent as to present a fibrillar appearance such as is seen in axone hillock of the spinal ganglion cells and around the nucleus. This alteration is probably due to growth changes, as was pointed out by the writer (1901[4]) in an earlier paper.

So far as my observations go, the fibrillar structure of the ground substance in the nerve-cells of the white rat is merely a modified network, and consequently it cannot be compared with the fibrillar structures described by Bethe and Apàthy.

### III. FINER STRUCTURE OF THE AXONES AND DENDRITES

Both the axones and dendrites are direct prolongations of the cell-body and present wide variations in their shape, size, and length, according to the cell-bodies from which they arise.

1. *Structure of the axones.*— An axone originates, as a rule, from a specially differentiated portion of the cell-body known as the "axone hillock." The axone hillock appears under the microscope as a cone, being clearly marked off from the surrounding cytoplasm by the absence from it of the Nissl granules. Under a higher magnification this area of the axone hillock is seen to be composed entirely of delicate filaments formed by rows of neurosomes and stains more intensely than the rest of the cell (Plate XIII, Fig. 1). These delicate filaments run convergently from the cell-body to the axone and produce well-known radial arrangement of the filaments. These filaments, however, are not real fibrils, but, as has already been mentioned, they are modifications of the reticulum, and the so-called fibrils in this region are connected with one another by the delicate side branches. In other words, the axone, like the cell-body, is composed of a reticular arrangement of the cytoplasm and may be regarded as an extension of the cell-body proper. The ground substance, or the reticulum, of the cell-body, as well as the axone, is composed of cyto-microsomes and neurosomes. The neurosomes in the axone seem to be more differentiated than those in the cell-body proper, for they show a stronger affinity for acid dyes, especially in the terminals of the axones. It is interesting to note that the pseudo-fibrils in axones are packed very densely, and therefore the real structure of the primitive reticulum is hard to make out. The structure of the axone may be well studied by examining the cross-sections of the terminals (Plate XIII, Figs. 2, 3, 4; Plate XIV, Figs. 5, 6.) The neurosomes which form the terminals of the axis cylinder are very conspicuous, both by their size and by the manner in which they stain. The size of the individual neurosome in such terminals is a trifle larger than in the axone proper and stains a more intense red. It is already known that the

axis cylinder at its end enlarges greatly and forms the so-called "axis cylinder plate." An enlargement of the axone terminal may be seen in Figs. 5 and 6. Especially in Fig. 5, where the nerve-fibers enter into the granular layer of the cerebellar cortex, there is to be seen an enormous enlargement of the axones to several times their original diameters. A detailed description of the structure of the axone terminals and their relation to the surrounding neurones will be given later.

2. *Structure of the dendrites.*— The internal structure of the dendrites shows a close resemblance to that of the cell-body. Besides the ground substance which stains faint red, as in the case of the cell-body proper, it contains Nissl granules. Unlike the axone the dendrite contains but a small amount of the ground substance, and, further, the size of the individual neurosomes is approximately the same as that of the cyto-microsomes, where they stain more faintly than the neurosomes in the axone. In other words, the neurosomes in the dendrites do not show much differentiation from the cyto-microsomes. The reticulum, however, presents a marked alteration, exhibiting in some cases (Plate XIII, Fig. 4) a fibrillar arrangement. A most interesting feature of the dendrite is the nodules or gemmules which develop along its periphery. By the Golgi technique they stand out like pin-head prolongations or knobs. The presence of these gemmules on the dendrites has been denied by Hill (1896), while the other investigators regard them as very important and constant structures in certain forms of nerve-cells (Van Gehuchten, 1897, Cajal, and others). Still another interpretation has been made by Demoor (1896, 1898), who considers the moniliform appearance of the dendrite as a condition in which the gemmules are partially retracted and regards them as important for the normal activity of nerve-cells. I agree with the view which regards these structures as a constant character of certain forms of the nerve-cells. This knob-like structure can be seen not only in specimens prepared by the Golgi technique, but also in those prepared by my own method. In this case we can see clearly the internal structure of the gemmules and their relations to the main body of the dendrite. The gemmules are nothing more than a local extension of the ground substance of the dendrites, and a more or less modified reticulum can be seen within them in many cases (Plate XIII, Fig. 4). It is difficult, however, in some instances to distinguish the gemmules from the surrounding structures, when a large number of the neurosomic chains forming the axone terminals surround the dendrite very densely. Careful observation shows that the neurosomes in the gemmules stain less deeply than those forming the terminals. The accumulation of neurosomes to form gemmules is shown in Fig. 4, which has been drawn from the cells in the cerebral cortex of the adult white rat.

## IV. TERMINATION OF THE AXONE ON THE DENDRITES AND CELL-BODIES

1. *Termination of the axone on the cell-body.*—The actual termination of the axone on the cell-body as well as a diffused network of the nerve-fiber terminals surrounding the cell-body and forming the so-called "pericellular network" has been

observed by Semi Meyer (1896), Held (1897), Ramon y Cajal (1899), Golgi and his students, and others.

In certain kinds of neurones the present writer has also been able very clearly to see these phenomena in his preparations. The cerebellar cortex is a most favorable locality in which to see the termination of the axones on the cell-body. It is a well-known fact that the Purkinji cells are surrounded by the terminals of the collaterals of the so-called basket cells, located in the molecular layer. Fig. 5 (Plate XIV) illustrates these terminations. In this figure the Purkinji cells are represented in sepia and the axone endings by a deep red. As can be seen, a large number of the neurosomes appear surrounding the basal portion of the cell-bodies together with their axones, and form a basket; while the upper part of the cell-body is in contact with a small number of the neurosomes along the cell-wall. According to the existing view, the basket-forming fibers are derived only from the collaterals of the axones of the cells which lie in the molecular layer. Contrary to this view, the writer believes that the fibers which form the basket have at least two sources of origin: that is, one from the molecular cells and the other from the so-called moss-fibers. This conclusion was drawn from the following evidence: by examining Fig. 5 (Plate XIV) one can easily see that the main part of the fibers which form the basket including the basal portion of the Purkinji cells descend toward the medullary layer and become continuous with some of the fibers in that layer. In other words, some of the fibers which enter into the granular layer enlarge very much and ascend as far up as the Purkinji cell layer, where they surround the latter very intimately and form the so-called "basket" in company with the descending collaterals from the cells in the molecular layer. In the same figure the sections of the main trunks, as well as the lateral branches of the moss-fibers in various planes, are shown distributed throughout the granular layer. In many cases these cross-sections of the moss-fibers are surrounded by the neurosomes which stain lightly. These structures, formed by the two kinds of the neurosomes, correspond probably to the glomeruli; and the neurosomes which stain lightly are identical with those which form the dendritic branches of the granular cells, while the rest of the neurosomes are those which form the moss-fiber.

An appearance similar to the basket of the Purkinji cells has been observed by the writer in the case of the cells in the Ammon's horn. Fig. 4 (Plate XIII), which has been drawn from the cells in the Ammon's horn, in the adult white rat shows the basal portion of the cell-body densely surrounded by the axones of another neurone forming a pericellular network.

The termination of the nerve-fibers on the cell-body in the corpus trapezoideum has been described by several investigators, especially by Held (1895). In the case of these neurones, according to him, the terminals of an axone come into contact relation with the cell-body of another neurone, yet one can always make out where the protoplasm of one neurone ends and where that of the second begins. Further, the line of demarkation is more refractive than the adjacent protoplasm. He finds, however, that

this refractive limiting line is not demonstrable in the adult and comes to the conclusion that during the processes of growth the protoplasm of the related neurones fuses.

As is stated by Held, the cells in this locality are very favorable for the study of the termination of the axones. As Fig. 6 (Plate XIV) shows, the terminals of an axone come in contact with the cell-body along a groove or an elongated depression. This groove on the cell-surface may coincide with the refractive area of Held. In most cases more than one axone terminates on a single cell-body. Fig. 6 was drawn from the material taken from a young white rat having a body-weight of 4.5 grams. In this stage a number of axones terminate on each cell-body. No special area for the termination of the axones appears, since they are found in all regions of the cell-body, sometimes at the center and sometimes at the end of it. In all cases the terminals of the branches present mere contiguity to the cell-surface, and neither fusion of one with the other nor a pericellular network of the axones is found. It is to be noted that these observations apply to the white rat, while the observations of Held were made on the rabbit. Whether the cell-body in the rat becomes fused with the axones in adult life has still to be determined.

A relation between axone and cell-body similar to that in the corpus trapezoideum can be observed in the ventral horn cells of the spinal cord. Fig. 2 (Plate XIII), which was drawn from the preparation of an adult white rat, illustrates this. In this figure the cell-body is represented by sepia while the axone endings are colored an intense red.

2. *Termination of the axone on the dendrites.*—As has already been mentioned, the gemmules are lateral extensions of the dendrites, and their essential structure is the same as that of the dendrites. A careful observation of the preparation shows that the axones in most cases surround the dendritic branches and approach so closely to the gemmules that these two structures often come into contact. As Fig. 4 (Plate XIII) shows, the cell-bodies in the Ammon's horn are densely surrounded by the axones and some of the latter climb along the surface of the dendrites and there come into contact with the gemmules. This relation is even more clearly shown in the cerebellar cortex. It is already known that the dendrites of the Purkinji cells are densely surrounded by several kinds of the axones ; namely, those of the granular cells, those forming the climbing fibers, and those which form the moss-fibers. The axone terminals which surround the dendrites come, in most cases, actually in contact with the latter. Fig. 5 (Plate XIV) shows such a relation between the two processes where the dendrites are represented in sepia, while the axones are colored an intense red.

The so-called "glomeruli" formed by the axones and dendrites form the most favorable structure for the study of an intimate relation between the two processes. This structure is found best developed in the olfactory-bulb and less developed in the granular layer of the cerebellar cortex. The olfactory glomeruli in Fig. 3 (Plate XIII) were

drawn from that of the new-born white rat having a body-weight of 4.5 grams. For convenience the axones are represented in red, while the dendrites are in yellow. Although the olfactory glomeruli are of very complicated structure, owing to an intricate arrangement of the two kinds of the processes, yet, after knowing the character of the axone and dendrite as determined by the neurosomes in them, one can easily see that in many cases a single long and apparently continuous filament is composed of two differently characterized parts; that is, the neurosomes in one portion are much larger and stain more deeply than those found in the other portion. In other words, these apparently continuous lines are composed of two different structures, the axones and the dendrites. In the case of the glomeruli in the granular layer of the cerebellar cortex, continuous filaments formed from two sorts of processes, as observed in the olfactory glomeruli, were not found, but a mere contiguity of the two processes, such as is noticed in the dendrites of the Purkinji cells and the axones which surround them, was all that could be observed.

## GENERAL REMARKS

The history of the investigations on the neurone has been beautifully summarized by Goldscheider and Flatau (1898), Barbacci (1899), Barker (1899), Robertson (1899), Soury (1899), and Van Gehuchten (1900), but in order to show the bearing of our own observations, it will be necessary briefly to review the more important theories concerning the neurone.

According to the most prevalent view, the "neurone" or the nerve-cell with all its processes may be regarded as an independent element, from the anatomical standpoint; consequently the entire nervous system is an aggregation of those independent elements. This view was first brought out by Waldeyer (1891). He says:

> Das Nervensystem besteht aus zahlreichen untereinander anatomisch wie genetisch nicht zusammenhängenden Nerveneinheiten (Neuronen). Jede Nerveneinheit setzt sich zusammen aus drei Stücken: der Nervenzelle, der Nervenfaser und dem Faserbäumchen (Endbäumchen). Der physiologische Leitungsvorgang kann sowohl in der Richtung von der Zelle zum Faserbäumchen als auch umgekehrt verlaufen. Die motorischen Leitungen verlaufen nur in der Richtung von der Zelle zum Faserbäumchen, die sensiblen bald in der einen, bald in der anderen Richtung.

This view of Waldeyer, or the neurone doctrine, has been somewhat modified since Held, in 1896, noticed in some neurones an actual contiguity of the axones both with the cell-bodies and dendrites. Held's observation was very soon confirmed by a number of investigators and was further extended to another group of neurones. Held's observation, however, does not oppose the neurone doctrine, for he notices a mere contiguity of the axones with the cell-body and dendrites and not an organic continuation of one into the other. In the following year Bethe (1897) published an article in which he claims that the nerve-cells and dendrites contain a great number of primitive neuro-fibrils which run toward the axone and form the nerve-fiber. That is, the nerve-fiber is composed of these primitive fibrils. He believes, further, that the fibrils

of one neurone enter into the nerve processes of other neurones, and thus two neurones become continuous by means of these primitive fibrils. The observations were made on crustacea. Apàthy's (1897) observation on the lower animals (annelids) contradicts radically the neurone doctrine, for he was able to follow the primitive neuro-fibrils which come from one ganglion cell and enter into the cell-body of another element, where they become fused with the protoplasm. Anastomosis of the axones with dendrites has been observed by several other investigators, for instance, Ballowitz (1893), Heymans and Demoor (1894), and others; but in these cases always in the peripheral system. Thus Gerlach and Golgi's hypothesis of a diffuse network of the nerve-processes has been revived through a more careful investigation of modern neurologists.

It is impossible at the present moment to say which of these views is correct, since we do not know absolutely which technique shows the tissue in most nearly normal condition. But after examining the results obtained by several investigators, it seems to be quite reasonable to say that Golgi's silver-nitrate technique is not effective enough to bring out the minute structures of the neurones, and, further, it acts on the tissue so irregularly that in some cases even the same tissue in the same condition presents a widely different appearance. In addition, the ordinary silver-bichromate method does not show the internal structure of the neurones. Consequently, for the purpose of this discussion, results obtained by Golgi's technique can hardly be considered as at all conclusive.

As has already been mentioned, the nerve-cells in the white rat present a fibrillar structure owing to the parallel arrangement of the neurosomes. This structure, however, is merely a modified reticulum which has been very much elongated. In some cases several of these parallel lines of the elongated meshes combine together and form very thick strands. Further, these united filaments or strands are found throughout the cell-body, forming a very complicated network. In the case of the dendrites these united filaments are noticed most frequently. Now, comparing these figures with that of Golgi's endocellular network previously mentioned, one might expect the two figures to be identical, for this anastomosis of combined filaments in the cells in the white rat occurs only around the nucleus and in the neighborhood of the axone hillock, not in the hillock itself, and never occurs along the periphery of the cell-body, where wide meshes of a polygonal shape are alone visible. Golgi's endocellular network has a similar distribution within the cell-body. A similar arrangement has been observed in the cells of cerebral and cerebellar cortex. The only difference between Golgi's results and those of the present writer is that Golgi's network is much simpler than the latter and does not show any minute meshes formed by delicate filaments. This difference is due very probably to an insensitiveness of Golgi's technique, so that it does not bring out these minute structures.

It has been suggested by some investigators that Golgi's endocellular network might represent the system of the intracellular canaliculi of Holmgren. If Golgi's

endocellular network is really homologous to the canal system described by Holmgren, it should occur along the cell-periphery where this canal system is most abundant as well as larger in diameter. Further, as has been pointed out by Soukanoff (1902), these two structures do not show any similarity in appearance.

The present writer thinks also that the anastomosis of fibrils of Apàthy within the cell-body may be a homologous structure to both Golgi's endocellular network as well as to the network here described. Judging from its manner of distribution and position in the cell-body, they are nearly identical with one another. Slight variation in the structure depends upon the tissues taken from animals which are widely different. The more complex anastomosis of Apàthy are due to the greater accuracy of technique.

It seems to me, therefore, that the fundamental structure of the ground substance in the nerve-cell shows reticular arrangement, which, however, becomes sooner or later elongated, and thus the fibrillar appearance in the axone hillock, axone, and dendrite, and the complicated anastomosis in the cell-body, are brought out in the way previously described.

As will be seen from the previous description, certain nerve cell-bodies, such as Purkinji's, the pyramidal cells and the cells in the corpus trapezoideum and ventral horn of the spinal cord, are densely surrounded by the terminals of the axones, and in some cases not only surrounded, but some of the axones terminate on the cell-body and become contiguous with it. Further, the dendritic processes, especially the gemmules, are as a rule very densely surrounded by the axone terminals. In all these cases, however, those two kinds of structures are merely in contact with each other, and the present writer was not able to see any actual continuity between the two. Even in the case of the olfactory glomeruli, where the axones and dendrites unite and form a single filament, these two structures can nevertheless be clearly distinguished. I conclude, therefore, that, although the two structures appear continuous with one another, nevertheless the junction point can always be recognized by the differences in structures in either side of it.

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## EXPLANATION OF THE PLATES

### PLATE XIII

FIG. 1.—Spinal ganglion cell from a cervical ganglion of the adult white rat. Reddish-brown (surrounding the cell-body) represents the capsule which is composed of connective tissue. Several sheath-nuclei as well as a cross-section of a capillary containing the blood corpuscles are shown. Within the cell the larger red granules represent the neurosomes, while the smaller granules of the same color represent the cyto-microsomes. The nucleus which is represented also in red contains a single nucleolus (blue) and a large number of the oxyphile granules (red). Nissl bodies are represented in blue. The location of the axone hillock is indicated by the absence of the Nissl bodies.

FIG. 2.—A motor cell from the ventral horn of the spinal cord of the adult white rat. Lighter red represents the body of the motor cell which contains a spherical nucleus (slightly darker red) at the center. The dots of an intense red represent the neurosomes which form the axone endings. They terminate on the surface of the cell-body.

FIG. 3.—An olfactory glomerulus of the new-born white rat, having body-weight of 4.5 grams. Red lines represent the olfactory nerve-fibers, while the yellow lines represent the dendritic branches of the mitral cells. The neuroglia nuclei are represented in blue.

FIG. 4.—Cells from Cornu ammonis of the adult white rat. The larger cell (on the left side) shows a mode of termination of axones which are composed of a large number of the neurosomes. The small cell represents the internal structure of the cell-body. The neurosomes are represented by red dots, while the nucleus in which is a single nucleolus (blue) and a large number of the oxyphile granules (red) is outlined in red. Blue in the cytoplasm represents the Nissl bodies.

### PLATE XIV

FIG. 5.—The cerebellar cortex of the adult white rat. Purkinji cells and their dendrites are represented in sepia. Nerve-fibers and neurosomes are represented in red. Nuclei in both granular and molecular layers as well as the blood capillaries are represented with black.

FIG. 6.—Cells from corpus trapezoideum of the young white rat having body-weight of 4.5 grams. Each nucleus contains a single nucleolus (blue) and a large number of the oxyphile granules (red). Blue in the cytoplasm represents the Nissl bodies. Red lines (heavier) represent the terminals of the axones while the lighter lines in the outside of the cell-bodies represent either the neuroglia fibers or fine nerve-fibers.

All the figures were drawn from restained preparations (see the technique in the text) by free hand, using Obj. $\frac{1}{12}$ × OC, 4, Zeiss, except Fig. 5, which has been drawn by using Obj. 4, 0 mm. × OC. 4, Zeiss.

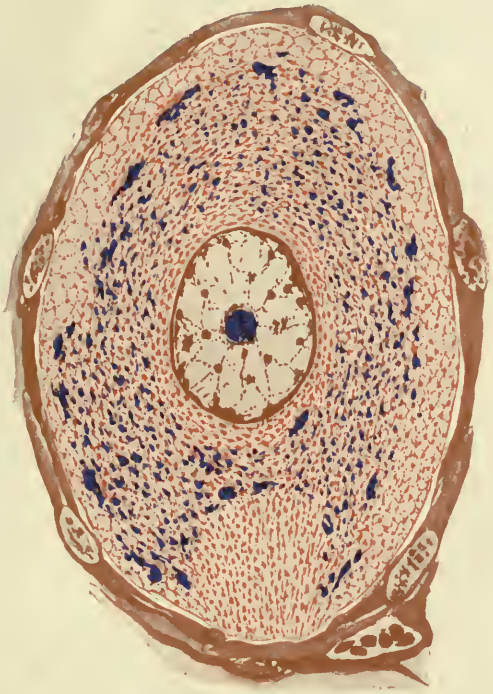

Fig. 1

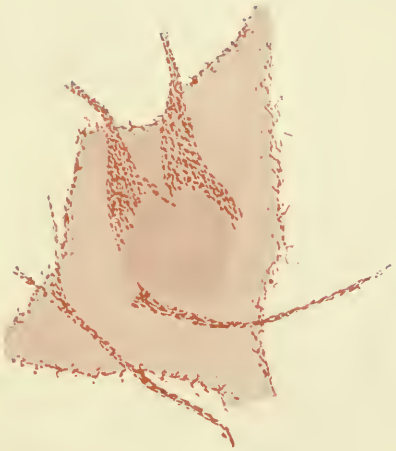

Fig. 2

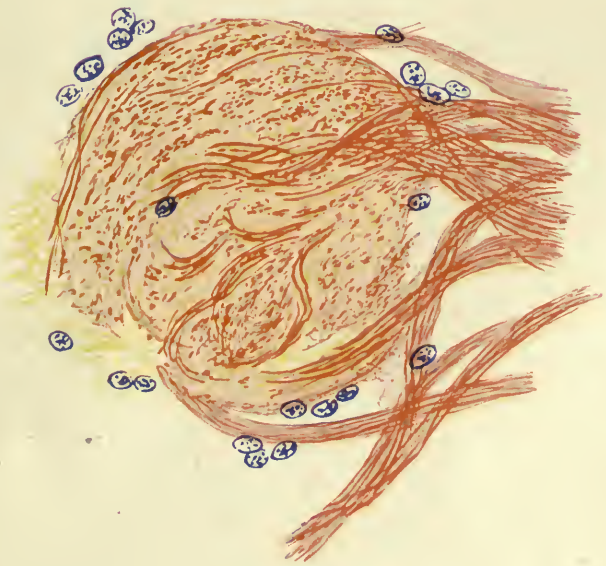

Fig. 3

Fig. 4

Fig. 1. Spinal Ganglion Cell from White Rat
Fig. 2. Ventral Horn Cell from White Rat. Axone Terminations
Fig. 3. Olfactory Glomerulus. Newborn White Rat
Fig. 4. Cells from Cornu Ammonis of White Rat. Gemmules

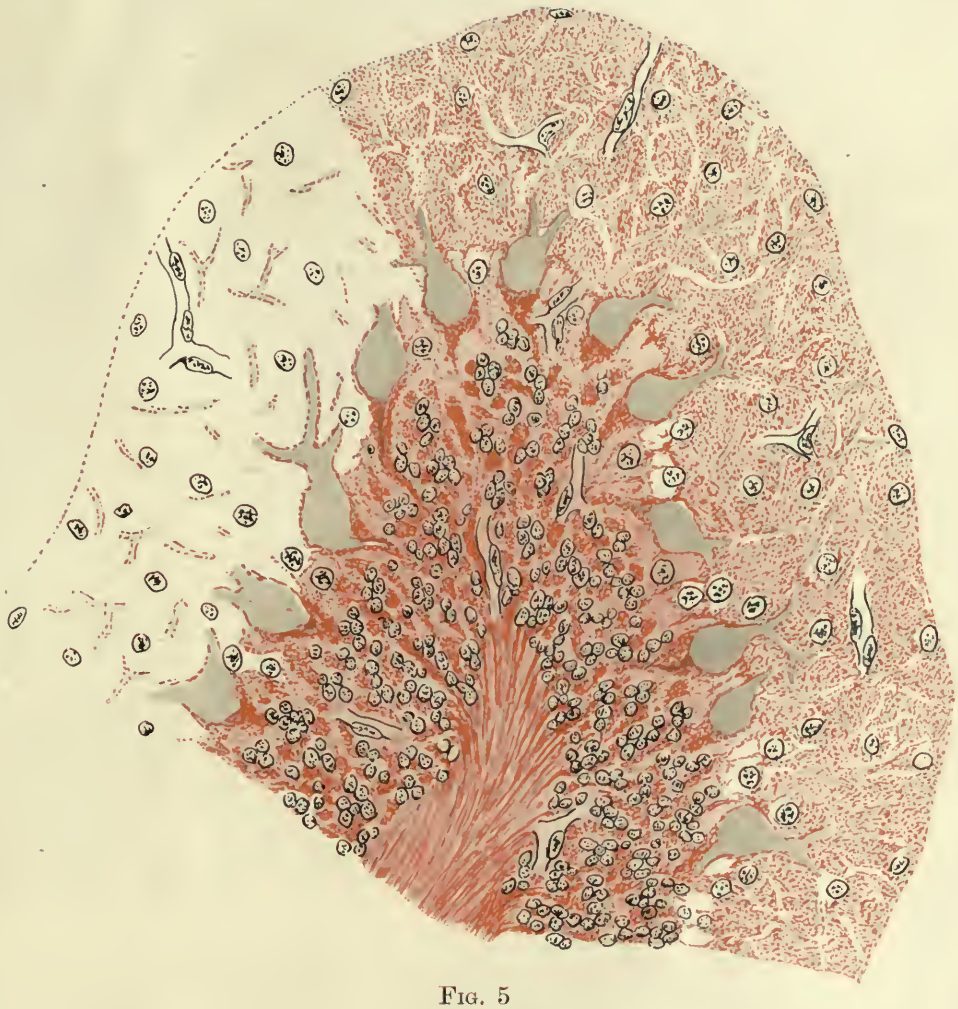

Fig. 5

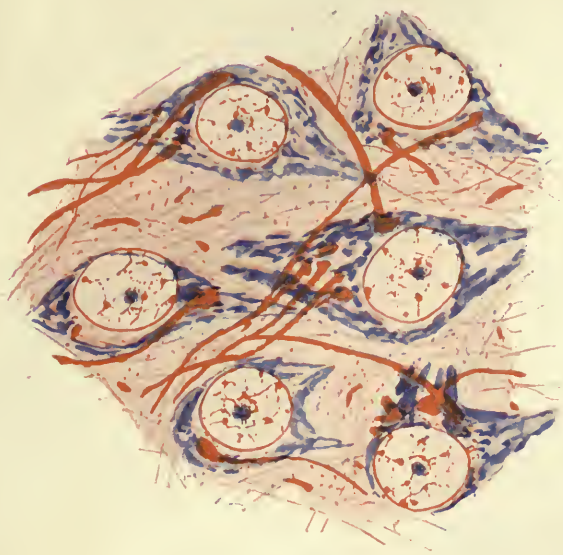

Fig. 6

Fig. 5. Cerebellar Cortex of White Rat. Axone Terminations.
Fig 6. Cells from Corpus Trapezoideum of White Rat. Axone Terminations.