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HISTOLOGY OF THE SENSORY ROOT OF THE TRIGEMINAL NERVE OF THE RAT (MUS NORVEGICUS)[1]

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During the course of a general study of the structure of medullated nerve fibers, a Weigert stained longitudinal section of the sensory root of the trigeminal nerve from a wild rat (Mus norvegicus) was examined. It presented, about 1 mm. from the brain stem, a sharply defined line of transition between the structure of the peripheral nerve trunk and the central nervous tissue, which change was revealed particularly by a difference in the intensity of staining. This change occurred along a regularly curved transverse line which was slightly convex peripheralward. A cursory examination of similarly prepared sections from the same and other animals showed that this condition was normal and not an artifact.

This picture has been described by a number of observers, more from the standpoint of microscopic relations than from the detailed histologic standpoint. A brief review of the most important communications will be both valuable and interesting.

R. Thomsen ('87) observed, in cross-sections of the human abducens and oculomotor nerves from a case of multiple alcoholic neuritis, that there were small, round, glistening placques or 'Herde' lying in the normal nerve tissue of the trunk and sharply delimited from it. They consisted of a horny substance staining readily in carmine. Oppenheim ('87) found similar placques in cross-sections of the human facial and hypoglossal nerves and designated them as the 'Herde' of Thomsen. The latter, having recognized that these 'Herde' were not specific

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for any disease, sought to explain them as degenerating ganglion cells. Oppenheim, on the other hand, considered them as normal structures but gave no clear explanation of their significance. Staderini ('90) found the 'Herde' of Thomsen in the human oculomotor, trochlear, abducens, facial, and vagus nerves, and showed that these placques were not to be considered as degenerating ganglion cells but as processes of neuroglia from the brain stem out into the nerve trunk. This he proved in serial cross-sections by tracing the continuity of the placques with the central neuroglia. A. Hoche ('91) referring to the neuroglia, mentioned tooth-shaped processes extending from the surface of the spinal cord in company with the nerve fiber bundles and ending abruptly a little distance peripherally. Lavdowsky ('91) in his communication on the neuroglia of the spinal cord, referred to the same arrangement and pictured such a condition in figure 7 of plate 16 accompanying his article. E. Redlich ('92), in describing the lesions occurring in the spinal cord and posterior nerve roots in tabes dorsalis, said that the degeneration began in those fibers of the posterior root which were of the intramedullary type, thus intimating the presence of two essentially different types of nerve fibers, the intramedullary and the extramedullary. Both Kölliker ('93) and Edinger ('93) agreed with Lavdowsky in describing processes of neuroglia extending from the spinal cord out into the posterior roots of the spinal nerves. J. Schaffer (worked in '90, published in '94) found that the neuroglia in the nerve trunks ended in a pointed cone-shaped termination, convex peripheralward. Obersteiner and Redlich ('95), completing their work in '94, observed, during the course of their study of tabes dorsalis, a constriction and pial ring on the posterior nerve roots at their entrance into the spinal cord, and that a short distance peripherally the medullary sheaths lost their staining property over a small zone, resulting in a narrow clear space, a transverse 'Aufhellung,' which was bow-shaped with its convexity outwards. Obersteiner ('95) and E. Redlich ('97) defended and added details to their observations, urging especially the importance of the change from extramedullary to intramedullary

fibers in its relation to the primary lesions of tabes dorsalis in the spinal nerves. K. Schaffer ('01) added the observation that the myelin sheaths of the extramedullary part of the root stained darker but less sharply than those of the intramedullary portion, the two being separated by the convex, non-staining line which had already been described as the 'Aufhellung.' Obersteiner ('01) reviewed all the previous observations on the structure of the posterior roots of spinal nerves. E. Levi ('06) published the results of a comparative study of the sensory roots of all the spinal nerves, dealing especially with the transition from peripheral to central nerve fibers. E. Hulles ('06) extended the work of Levi to the human vagus, acoustic, and trigeminal nerves, finding there very much the same relations as in the posterior roots of the spinal nerves. Bikeles ('07) substantiated these histological findings from a physiological point of view by finding a difference between the reaction to secondary degeneration in the fibers peripheral to and central to the change. J. Bauer ('08) reported the results of a careful study of the posterior roots of spinal nerves in many animals; Primates, Ungulata, Carnivora, Insectivora, Rodentia, Edentata and Marsupalia. He found in all classes the same structures that had been described for the human spinal nerves.

MATERIAL AND METHODS

The brown rat (Mus norvegicus) was selected to furnish material because of the ease with which it could be handled and the readiness with which perfectly fresh nervous material could be removed. The trigeminal nerve root was selected primarily because of the fact that the feature under consideration is there particularly well shown; also because it is easily exposed and readily removed. Each root used was taken out in such a manner that a portion of the semilunar ganglion and a portion of the pons were included for landmarks and orientation. Similarly obtained nerves from the laboratory white rat, guinea-pig, rabbit, and dog furnished a series for a brief comparative study.

Standard laboratory methods were used in differentiating the histological elements studied. The general appearance was observed in formalin fixed sections stained in hematoxylin and one of the following counterstains—eosin, acid fuchsin, congo red, and Van Gieson's mixture (picro-fuchsin). The axones were studied in sections stained by Ranson's pyridine-silver method, and in a few Weigert myelin sheath preparations which showed a peculiar differential staining of the axis-cylinders.[2] The myelin sheaths were stained by Streeter's paraffin modification of the Weigert-Pal method, by osmium tetroxide, and by Haidenhain's iron-alum hematoxylin, following fixation in Bouin's and Yoshii's fluids. The neurolemma, pia mater, and connective tissue sheaths were studied in sections and teased preparations stained by Van Gieson's method and the common protoplasmic stains. Huber's modification of Benda's first method and Kingery's modification of the same were used to demonstrate the neuroglia.

The neuroglia sections were cut at a thickness of 4μ and 5μ. while all others were either 8μ or 10μ.

For the more intimate study of the myelin sheaths and neurolemma, nerve fibers which had been separated by teasing were studied. An attempt was always made to obtain both the peripheral and central types of fibers in the teased preparations, and they were examined in the fresh condition or following fixation and one of the stains enumerated above.

The embryology was studied from a set of serially-cut, sagittal sections of sixteen rat embryos, the use of which was granted through the courtesy of Professor G. Carl Huber.

PERSONAL OBSERVATIONS

Rat—Mus norvegicus

The sensory root of the trigeminal nerve averages about 4 mm. in length in fixed material. The motor root crosses the ventral surface of the sensory root obliquely from the median to the

[2] Smith and Mair state that diffuse staining of the myelin and deep staining of the axone in Weigert preparations is due to too long 'chromation.'

lateral side, the two being quite closely bound together. At a distance averaging from 1 mm. to 1.5 mm. from the brain stem the combined roots are apparently very slightly constricted, the diameter central to this zone being slightly less than the diameter peripheral to the constriction. In nerves which are brittle from fixation or dehydration there is a great tendency to fracture along the plane of this constriction, transverse to the long axis of the root.

In favorable longitudinal sections of the trigeminal nerve roots stained by a myelin method, there is, along a transverse line corresponding to the plane of the constriction, a distinct demarcation between a central lightly staining portion and a peripheral darkly staining portion. Between the two there is often a very narrow unstained zone extending transversely across the roots. This line of demarcation is usually somewhat saucer-shaped, appearing, in a longitudinal section of the root, as a curved line with the convexity peripheralward. The nerve fibers may be grouped in fairly distinct bundles which, in crossing this transition, project unequal distances beyond it, thus making of the change a serrate transverse line.

The root distal to this abrupt change shows the structure which by comparison is seen to be typical of peripheral nerve trunks, with the exception that the fibers are not found in definite funiculi each surrounded by perineurium. The component tissues of the trunk are definitely arranged, and in fixed and stained sections show good preservation of relations and structure.

The root proximal to this abrupt change is more characteristic of central nervous system tissue in that the myelin stains less intensely, the nerve fibers are not so firmly bound together, and in otherwise well preserved material often show distortion forms and are separated by spaces due to shrinkage.

Because of this abrupt change from the type of fiber found in the peripheral nerve trunk to the type found in the central nervous system, this region is particularly favorable for a detailed study of the comparative histology of central and peripheral medullated nerve fibers. Both types, which have been

subjected to identical fixation, sectioning, and staining, can be observed together in the same high power microscopic field.

It is generally difficult to trace in section the continuity of single nerve fibers across this transition line because of their tendency to suddenly change direction and thus disappear from the plane of section, and because of the fact that for a short distance the myelin sheaths often fail to stain, leaving a narrow clear zone between the central and peripheral areas. Our knowledge of the function of nerve fibers gives us the right to assume the continuity of these fibers, and actual proof may be obtained by teasing them through the line of transition.

The abrupt line of change in the motor root does not always correspond with that in the sensory root, and it may be either slightly central or slightly peripheral to the latter. The greater size of the sensory root as compared to the motor root so facilitates the sectioning of the desired region that most of the preparations were made from, and all the descriptions will be confined to, the sensory root of the trigeminal.

The supporting tissues bear a very important relation to the transition line. The pia mater forms a delicate fibrous sheath for the brain stem and extends outward along the nerve trunks for a short distance, becoming continuous with the epineurium which, farther peripherally, fuses with the denser dura mater. The junction between pia mater and epineurium is somewhat indefinite but may be arbitrarily placed at the constriction marking the line of change from peripheral to central nerve fibers. In the living condition the only constriction of which one can truly speak is a decrease in the diameter of the trunk central to the line of change as compared to the diameter peripheral to the transition. At the junction of the pia mater and epineurium there is often a ring of thickened connective tissue which shrinks during fixation and causes an annular constriction which is really an artifact. From this ring, fine trabeculae and bundles of white fibrous tissue pass through the nerve parallel to the line of transition, and together with the neuroglia form a very delicate frame-work for the support of the nerve fiber bundles. In the human these inward prolongations have

been described as forming a lamina cribrosa through which the nerve fiber bundles pass, but in the rat such a structure is not visible. Minute blood vessels often accompany these septae toward the interior of the nerve trunk.

The neuroglia can be traced from the brain stem out into the sensory root of the trigeminal as far as the transition line but never beyond. In the same manner that the neuroglia is more dense around the periphery of the brain stem just under the pia mater, so it forms a cortical or 'bark' layer around the trigeminal trunk. It is less extensively found in the center of the root. The general direction of the neuroglia fibers is at right angles to the nerve fibers, especially in the periphery of the trunk and in the lamina cribrosa region, but as observed in 4μ or 5μ sections the neuroglia tissue is not dense in any portion and takes less part in the formation of the supporting framework in the rat trigeminal than credited with in the human trigeminal. As previously indicated, the neuroglia and bundles of pia mater here and there extend distally from the transition line as pointed processes, and confer a distinctly serrated appearance upon this line. These prolongations rarely intermingle with the supporting tissue of the peripheral trunk, and processes of the latter extending centrally do not fuse with the pia mater and neuroglia. Upon this fact probably depends the tendency of the root to fracture along the line of change.

The supporting tissue of the peripheral nerve fibers consists of endoneurium; since there are no funiculi between the pons and semilunar ganglion in the trigeminal of the rat, there is no true perineurium. The neurolemma must be considered as a part of the framework and although it is an integral part of the peripheral nerve fibers it will be considered here. In sections it is usually difficult to differentiate between the endoneurium and neurolemma, and the most satisfactory method of studying them is in teased preparations. A variety of stains were applied to the teased nerve fibers, the most important being Weigert's myelin sheath stain, hematoxylin and Van Gieson's mixture, and osmium tetroxide. In teased specimens the endoneurium is seen to consist of delicate fibrils running close to and parallel

with the nerve fibers. White connective tissue fibrils are present to the exclusion of the yellow elastic. Even the white fibrils appear wavy after teasing operations in which they are stretched. The fibrils are accompanied by cells which are chiefly of the fixed or fibroblastic type. The protoplasm is rarely seen, and the nuclei vary in shape according to their position and the pressure of surrounding fibers. Their apparent shape varies with the angle at which they are viewed. In general they are oval or flattened, staining fairly intensively and possessing distinct chromatin granules.

The neurolemma forms a close investing sheath for the peripheral nerve fibers, and can be seen as a membrane only where the fiber is broken, or over a neurolemma nucleus, or sometimes at the nodes of Ranvier. The neurolemma nucleus is oval and has even larger chromatin granules than the nuclei of the endoneurium. It can be readily differentiated from the latter only when seen in profile, when it appears to lie on the side of the nerve fiber in an indentation in the myelin, between two nodes of Ranvier. The neurolemma is seen as a thin membrane covering it. In osmium tetroxide stains these nuclei are frequently surrounded by dark gray or black granules, called Elzholz granules.[3] As mentioned before, the neurolemma and endoneurium stop abruptly at the transition line and do not intermingle with the pia mater and neuroglia.

It is interesting to compare the relative number of nuclei of all types found on the central and on the peripheral sides of the transition line. For this purpose 10μ sections stained in hematoxylin and eosin or acid fuchsin were used and the total number of nuclei in the same size microscopic fields each side of, and equally distant from, the transition line were counted by the aid of a ruled ocular. Using the number counted in a definite microscopic field central and adjacent to the transition line as unity, then the proportionate number in the same size field, adjacent to the transition peripherally, is expressed as a simple ratio. The table below, which gives the result of only four counts,

[3] For a complete description of the cells found in peripheral nerve trunks see the article by Doinikow.

TABLE I

Showing the proportionate number of nuclei on the central and peripheral sides of the line of change in the sensory root of the trigeminal nerve of the rat

FIXATION	STAIN	THICKNESS	PROPORTION OF NUCLEI	
			Central	Peripheral
Formol	Hematoxylin and eosin	10	1	7.0
	Hematoxylin and eosin	10	1	8.3
Mueller	Hematoxylin acid fuchsin	10	1	6.2
	Hematoxylin and eosin	10	1	5.9

shows that the nuclei are more numerous on the peripheral side. The figures given are typically average.

The axones were first studied in differentially stained sections, but this was unsatisfactory because of the difficulty encountered in tracing them through the transition because of their abrupt change in course at that region. Their continuity can best be determined in fresh teased fibers or in teased material stained by osmium tetroxide. The axones pass through with no perceptible change in size and without exhibiting varicosities or constrictions. They show no characteristic difference in staining reaction on the two sides of the change.

The structure which presents the most interesting differences and variations in passing through the transition is the medullary sheath. Text-book descriptions give as the main morphological difference between peripheral and central nerve fibers, the absence of the neurolemma from the latter. It is true that this plays a rôle in their differentiation, but it is inconceivable that the presence or absence of neurolemma should determine all the differential features between central and peripheral fibers as observed in the rat trigeminal.

In the search for other morphological distinctions it is necessary to consider what is known as the 'neuro-keratin network.' This term has called forth much discussion. One group of writers maintains that the keratin-like network, insoluble in alcohol, which is seen in many Weigert myelin sheath preparations, is a preformed meshwork which serves as a support for the myelin during life. Another group contends that the network is purely an artifact, the result of the precipitation, from

colloidal suspension, of a certain chemical constituent which may be called neuro-keratin. A reasonable middle-ground, supported by the facts briefly mentioned below, is to assume the presence of a framework for the myelin and to consider the variations in size and arrangement of this framework to be artifacts dependent upon the methods of preparation. Although unable to substantiate any claim upon purely morphological studies, we must recognize that variations in the appearance of this framework in fixed nerve fibers may depend upon a varying chemical reaction, the result of differences in the fundamental arrangement of the substance in question, or the result of varying precipitation pictures due to the reaction of different reagents upon a uniform substance. In fixing trigeminal nerves previous to the application of Weigert's myelin sheath stain, it was found that the neurokeratin figure varied with the chemicals used or even with varying strengths of the same fixative. By rough handling or a long wait before fixation a very coarse network was secured, which in some cases presented the characteristic funnel-shaped bodies described by various authors. In the same way that Fischer ('99) worked out fixation pictures for many chemicals in their action upon protoplasm, definite pictures can be determined for the more characteristic fixatives in their action upon myelin. Conversely, the appearance of this network varies in fibers from the central and peripheral nervous systems when subjected to identical treatment. The best place to compare the two types of fibers is in a region showing an abrupt change from one to the other. In the sensory root of the trigeminal, where both the central and peripheral fibers have been handled identically in staining, the neuro-keratin network shows definite and rather uniform differences on the two sides of the transition. In the peripheral fibers there is usually a pronounced, regularly arranged, and fairly coarse meshed network. Because of this effective support the myelin sheath usually retains its tubular shape and is rather infrequently collapsed. The fibers therefore lie in quite close contact leaving few interstices in the peripheral root. On the other hand, the central fibers usually contain a loose, frail, irregularly

arranged meshwork of neurokeratin which does not prevent many of the fibers from collapsing. The resulting distorted fibers leave shrinkage spaces in the root central to the transition.

A slight difference in the diameter of the peripheral and the central fibers exists. This is emphasized beyond the normal proportion in Weigert myelin sheath stains, but is better represented in osmium tetroxide preparations in which the myelin is well preserved. In carefully teased specimens stained by the latter method, central and peripheral fibers from the same nerve were measured by means of camera lucida projection and a ratio determined between the measurements. From a series of such counts the average diameter of the central fibers in the nerves examined was found to be 8.2μ, with a range from 1.2μ to 12.5μ, while the average diameter of the peripheral fibers was 9.2μ, the range being from 1.2μ to 13μ. Taking the measurement of the central fibers as unity, the ratio of their diameter to that of the peripheral fibers is 1: 1.12. This may be an exaggeration of their normal ratio during life, because we cannot state exactly the relative shrinkage effect of osmium tetroxide upon the two types. Further, these figures do not mean that there are no fibers smaller than 1.2μ, but rather that those were the smallest fibers which took the stain enough to be visible.

The relatively deeper staining of the peripheral myelin sheaths as compared with the central is well revealed in osmium tetroxide, Weigert myelin sheath, and Haidenhain's iron-alum hematoxylin preparations. This is the factor which really confers upon the sections the sharply defined line of change. A region such as we have under consideration is the most suitable place to demonstrate this difference because here it is possible to treat the two nerve fiber types by identical processes, thus ruling out the variations due to inevitable differences in method when treating two pieces of tissue separately. The difference in staining reaction in such sections is not one of quality so much as of degree or intensity. In osmium tetroxide both the central and peripheral myelin are stained brownish-black, but the peripheral is of an appreciably deeper shade. Of the possible explanations of this condition at least two natu-

rally suggest themselves. First, in mass staining the two different kinds of supporting tissue surrounding the fibers may so influence the penetration or bleaching of the stain as to bring about the result above noted. Second, the two shades may be the physical expression of actual chemical differences between central and peripheral myelin. When we remember that the reagent is identical, this explanation seems more possible. Moreover, in tissue which has been sectioned, the myelin is fully exposed to the action of the chemical, thus partially escaping the protective influence of the supporting tissues upon the reaction. The view that myelin in the central nervous system is deposited by a different agency than that in the peripheral system also lends support to the second explanation; but if myelin is everywhere deposited by the axones, it would be difficult to assign it a varying chemical constitution in different parts of the nervous system.

In many preparations there is a narrow clear space between the central and peripheral portions of the root, which is apparently due to an interruption of the myelin, the heavily staining peripheral sheath ending as a rounded cone through which the axone projects, passing through the narrow clear zone uncovered by myelin. In a few favorably cut fibers, myelin was seen to be reacquired on the central side at a distance of about 30μ from its interruption. A suggested explanation of this apparent lack of myelin in stained sections is that the supporting tissue of the lamina cribrosa region prevents the penetration of the stain to the myelin. This may be true in mass staining, such as with osmium tetroxide, but is less convincing when the same condition is found in preparations stained on the slide after sectioning. The view that myelin is deposited through the agency of different structures in the peripheral and central fibers and that there is a gap between these structures at the place under consideration might be advanced as an explanation of the phenomenon. If we accept the statement that all myelin is deposited through the agency of the axones, this explanation is less plausible. The fact that Bauer ('08) found this clear space to be inconstant in a large comparative series of the posterior roots of spinal nerves, makes its significance very obscure.

COMPARATIVE HISTOLOGY

The sensory roots of the trigeminal nerves of a short series of mammals were examined in order to gain an idea of the extent and character of this transition in the more common laboratory animals. The sections from the white rat (Mus norvegicus albinus) show exactly the same features as those from the brown rat described above, and outside the variations normally incident to a series of sections from one animal, there are no peculiarities to distinguish it from the wild variety. In the guinea-pig preparations the only constant difference noticeable is the slightly greater curve of the transition line, which forms a peripherally directed cone with rounded apex. This animal furnishes good nerve material for the application of the neuroglia staining technique as modified by Huber for use with mammals other than human. In the rabbit trigeminal the connective tissue lamina cribrosa is more pronounced and bundles of fibrous tissue can often be seen running at right angles to the nerve fibers. The transition forms more nearly a straight line. The nerve fibers are grouped into bundles which are more definite than those of the rat. The line of change is relatively the same distance from the brain stem as in the wild rat. The dog shows a very distinct and abrupt change from peripheral to central type of fibers. The transition line is relatively near the brain when its position is compared with the diameter of the trunk. Instead of always showing a simple outwardly convex line, the curve is often doubly convex or bow-shaped with both convexities directed peripherally. The contrast in staining on the two sides is very pronounced.

EMBRYOLOGY

The work of Harrison and others has taught us that the nerve fibers grow out from their neuroblast cell bodies by direct extension, and become anchored in their permanent position at an early stage of development. The sensory roots of all nerves develop from the neural crest, the neuroblasts in the latter sending processes centrally to the spinal cord and peripherally to the region of the future sensory ending. Harrison ('04) has

showed us that the extension of these processes is accompanied by the migration of certain cells from the crest which give rise to the neurolemma sheath cells or Schwann cells.

In sections of the neural tube and semilunar ganglion anlage in a rat embryo of 6 mm. length (crown-breech) the centrally directed processes of the neural crest cells can be traced into the marginal layer of the neural tube, passing through the external limiting membrane. Accompanying this definite embryonic nerve trunk are numerous cells with small, oval, lightly staining nuclei interspersed between the fibers. These extend only as far as the anlage of the pia mater and to the external limiting membrane which lies closely adherent to the marginal layer and is formed by the interweaving of the peripheral process of the spongioblasts. Along this line these cells cease abruptly in a curve corresponding to the normal surface curve of the brain stem. These nuclei belong chiefly to the developing sheath cells which apply themselves to the sides of the growing axones. In a 6 mm. rat embryo they are fairly evenly distributed in the trunk and in a 10 mm. embryo they have surrounded all the fibers, but together with the ingrowing mesodermal cells have also gathered into rows in many parts of the trunk, marking the development of fiber bundles.

In distinction to the peripheral trunk, the marginal layer of the neural tube shows a less intense staining reaction. This is primarily due to the almost complete absence of nuclei and cannot be assigned at this time to different types of myelin, because such a chemical substance is not present. Its acquisition at a later stage accentuates the differential staining. This early line of change from peripheral to central fibers corresponds to the pia mater anlage and external limiting membrane, both of which must be pierced by the developing axones in their exit or entrance, and which act as a barrier to the ingress of the sheath cells.

These relations persist and may be demonstrated in sections of increasingly older embryos. During the further development, the nerve trunk becomes better differentiated from the surrounding mesenchyme, the sensory root is relatively longer

compared with its diameter, and the nerve fibers become more definitely grouped in bundles as the supporting tissue assumes definite arrangement. In an 18 mm. rat embryo the pia mater is a definite membrane and is separated from the denser anlage of the dura mater by a slight amount of loose-meshed tissue, the arachnoid anlage. At this stage the semilunar ganglion lies close to the pons on the one side and to the bony foramina for its divisions on the other so the whole trunk is relatively short. During the development of the skull, when the distance from the foramina for the trigeminal divisions to the attachment of the sensory root on the pons is gradually increasing, it is conceivable that enough tension is put upon the roots to cause the line of change, representing the original line of pia mater and external limiting membrane, to be drawn slightly away from the surface of the brain in an outwardly convex bow. This view is substantiated when we examine sections of a 23 mm. rat embryo in which the arachnoid tissue surrounding the trigeminal root is relatively much increased because of the greater distance between the pia mater and dura mater along the course of the nerve. The effect is seen in a section of a 30 mm. rat embryo where the transition line, even before birth, is slightly external to the brain surface. The migration of this line, due to inequality between growth in the nerve roots and in the skull, takes place chiefly in the early post-natal period, because it is slightly established in a 30 mm. embryo and shows well in a young rat about four weeks after birth. The position of this line of change may be regarded as the result of varying degrees of, or the lack of, traction upon the trunks during the rapid development of the body which causes separation of the attached ends of the nerve at a slightly greater rate than compensated by the growth of the fibers themselves.

For the practical importance attached to this transition line in its relation to the etiology of tabes dorsalis, the reader is referred to the articles by Nageotte, Obersteiner and Redlich, Levi, and the authors cited by them.

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CONCLUSIONS

1. In the sensory root of the trigeminal nerve of the rat (Mus norvegicus), about 1 mm. from the pons, is an outwardly convex line which marks an abrupt change from the peripheral to the central type of nerve fibers.

2. The peripheral supporting tissues, endoneurium and epineurium, together with the neurolemma, meet, without intermingling, the central supporting tissues, neuroglia and pia mater, to form an indefinite lamina cribrosa through which the bundles of nerve fibers pass.

3. The axones extend through this change uninterruptedly and unaffected morphologically.

4. The peripheral myelin shows—

a. A deeper coloration than the central when both are identically treated with myelin stains.

b. A 'neuro-keratin network' which is more prominent and more regular than that in the central fibers when both are identically treated.

These facts may be interpreted as showing distinct chemical and physical differences between the central and peripheral myelin.

5. A number of other mammals show a similar or identical picture in the sensory roots of their trigeminal nerves.

6. This change may be considered as occurring at the line where the pia mater and external limiting membrane surrounding the embryonic nervous tube were pierced by the growing processes of neuroblasts, these membranes acting as barriers against the entrance of sheath cells into the neural tube. The position of this line depends upon the amount of tension to which the root is subjected during development.

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