Dr Frederick W. Mott
London —

With the respects & esteem of the
Authors.

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EXPERIMENTAL RESEARCHES ON THE CENTRAL LOCALIZATION OF THE SYMPATHETIC WITH A CRITICAL REVIEW OF ITS ANATOMY AND PHYSIOLOGY.*

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INTRODUCTION.

The anatomy and physiology of the sympathetic nervous system have long been favorite subjects for the study and speculation of scientists. In latter years the method of metal impregnation, inaugurated by Golgi, and the methylene blue method, first successfully utilized by Ehrlich, have lent themselves to the study of this obscure part of the body, and many investigators, of whom we may mention Kölliker, His, Ramon y Cajal, Van Gehuchten,

* The above monograph was completed as early as May, 1897, when it was sent to Paris and entered among the essays for the Lallemand prize of the Academy of Sciences. The manuscript after much delay incident to the awarding of the Academy prizes was finally handed to the editors of the

Retzius, Dogiel and Sala, have illumined our knowledge of the minute structure and architecture of the sympathetic nervous system. Thus far, however, few authors have undertaken to determine the manner in which the sympathetic is connected with—or better said—localized in the spinal cord and brain. Of these few, the name of Gaskell deserves to be mentioned first. By a most ingenious plan of investigation Gaskell has studied the relation of the central nervous system to the visceral nerves, and has reached definite conclusions regarding the localization of the latter in the cord and brain. These conclusions we shall relate in another chapter.

Strangely enough, Gaskell's investigations have not attracted the notice which they deserve; indeed, we miss mention of them in many of the best known text-books on the anatomy of the nervous system. Moreover, some of his conclusions have been contested and denied by Mott. These facts seem to justify further research in the same field and encouraged us to undertake the investigations regarding the localization of the sympathetic nerves in the spinal cord and brain which form the chief subject of this monograph. By such investigations we hoped

ARCHIVES OF NEUROLOGY AND PSYCHOPATHOLOGY. Then further delay ensued owing to the fact that the illustrations had to be redrawn as the Paris Academy of Sciences retained the original drawings. This in turn brought up other obstacles postponing the publication to the present date.

The paper was presented at the 1898 meeting of the American Neurological Association, an abstract of which appeared in the *Journal of Nervous and Mental Diseases*, 1898, p. 661.

The monograph having been completed in May, 1897, naturally only the literature preceding that date has been utilized. Although since that time, as far as we know, no investigations have appeared in the literature necessitating any change of view in our researches, one or two contributions (for instance the valuable work of Matthews on the Physiology of Secretion—Annals of the New York Academy of Sciences, Dec., 1898)—seem to us to embody very important views on the general anatomy and physiology of the sympathetic, and are referred to in the parts of the monograph on that subject. Aside from this, and the addition of a final chapter on Disease of the Sympathetic in Insanity, the paper stands practically as originally written.

also to further a better understanding of the genesis and significance of certain clinical phenomena which are now enshrouded in obscurity, such as functional disturbances of the bladder and rectum in central and peripheral diseases; the occurrence of gastric, vesical and other crises in tabes; the trophic lesions and disturbances of the vegetative system in syringomyelia; and possibly also the so-called vasomotor neuroses.

In our researches we have adopted the experimental or physiologico-anatomical method, so-called, which we believe has been of inestimable value in furthering the knowledge of the functions of the nervous system, although great discretion has to be used in applying directly to man the conclusions reached from study of the higher animals. There is no doubt, however, that the structure of the sympathetic nervous system in the higher mammalians has much analogy with that in man; consequently the results of investigations made on the former can be homologized to great extent for the latter.

So much importance is attached to a knowledge of the structure and function of this part of the nervous system that we consider it fitting to precede our own researches with a review of the facts regarding the anatomy, physiology and histology of the sympathetic. In reviewing the anatomy we have consulted freely Thane's account of the sympathetic in Quain's Anatomy as well as the work of Hoffmann and Rauber. In the chapters reviewing the physiology we have frequently consulted Herrman's text-book and occasionally that of Foster and others.

Chapter I.

GENERAL SURVEY OF ANATOMY.

In general terms the sympathetic nervous system is composed of: 1. The great gangliated cords. 2. The intermediate or central nerve plexuses. 3. The peripheral plexuses. 4. The terminal or monocellular ganglia. The general structure and topographical relations of each of these will first be considered, and, afterwards, the general relations of these divisions to each other and the central nervous system.

I.—*The Great Gangliated Cords.*—The great gangliated cords (sympathetic cords, sympathetic nerves, trunci sympathici, Grenzstrang des Sympathicus, nerf grand sympathique) consist of a series of ganglia (sympathetic ganglia, ganglia trunci sympathici) united to each other by longitudinal cords, the so-called *rami internodiales.* These two gangliated cords are placed symmetrically, partly in front and partly to the side of the vertebral column, and extend from the base of the skull to the coccyx. The internal carotid nerve which emanates from the uppermost cervical sympathetic ganglion must be considered the upward continuation of the sympathetic cord into the region of the head. Some of the cephalic ganglia, viz.: the ciliary, the sphenopalatine, the otic, the submaxillary, likewise the cervical ganglion of the pneumogastric, and probably also the ganglion petrosum glosso-pharyngei must be considered as homologues of the ganglia of the great sympathetic cords.

The two great gangliated cords and their homologues in the cranial division of the sympathetic have the following connections:

(1).—*The Interfunicular Cords or Rami* (*rami interfuniculares*).—These serve to unite the two great gangliated cords and are developed to the greatest extent in the lumbar and sacral portions of the sympathetic nerves.

(2).—*The communicating rami* (*rami communicantes*), establish a connection of the sympathetic ganglia with the cerebro-spinal nerves. The ganglia are severally connected by these rami communicantes with the anterior primary divisions of the spinal nerves in their immediate vicinity. The rami communicantes are of two kinds, the white and the gray, the former consisting mainly of medullated fibres, the latter of pale fibres (Gaskell). In some instances these two kinds of rami are separate branches, in others they are united in one cord which then consists of a white and gray part. Having arrived in the spinal nerves, the fibres of the rami communicantes, according to Gaskell, take opposite directions, part of the fibres, contained mainly if not all in the white rami, pass into the spinal cord; the other part, contained chiefly perhaps exclusively in the gray rami, assume a centrifugal course, passing with the other fibres of the spinal nerve to the periphery.

The rami communicantes are represented in the cranial division of the sympathetic system by the so-called roots of the cranial sympathetic ganglia (the sphenopalatine, ciliary, etc.)

(3).—*The Peripheral Rami* (Hoffmann and Rauber) or *rami efferentes, seu afferentes.*—These are branches proceeding from the gangliated cord to the prevertebral plexuses or vice versa.

We now pass to

II.—*The Intermediate or Central Nerve Plexuses of the Sympathetic.*—Here it will be convenient to distinguish as Thane (Quain's Anatomy) proposes:

(1).—*The Large Prevertebral Plexuses.*—These comprise three large aggregations of nerves, or rather nerves and ganglia situated in front of the spine and occupying respectively the thorax, the abdomen, and pelvis. They are single and are named respectively the *cardiac*, the *solar*, and the *hypogastric plexus.* These plexuses receive branches from the cerebro-spinal nerves, as well as from both the great gangliated cords. They constitute centres from which the viscera are supplied with nerves.

(2).—*The Smaller Plexuses of the Sympathetic.*—Most of these are in intimate connection with the great prevertebral plexuses, and are, in part, directly continuous with them, forming, so to say, sub-divisions of these. The remainder are united to the prevertebral plexuses by nerve filaments or cords. These smaller plexuses are also in intimate connection with each other, and probably receive likewise a supply of cerebro-spinal fibres. Among these plexuses we may class the *coronary*, the *mesenteric*, the *vesical*, etc.

III.—*The Peripheral Plexuses.*—Such plexuses as these are found in the wall of the intestines (Auerbach's and Meissner's) the œsophagus, the bladder, and other hollow viscera. They receive their supply of nerve fibres from the plexuses mentioned under division number two.

IV.—*The Terminal Monocellular Ganglia.*—These are the ganglia which Ramon y Cajal has found scattered in the interstices of glandular tissues, within the villi of the intestines, among the interstitial cells of the glands of Lieberkuehn, in the substance of the pancreas, the salivary glands, etc.

Theories of the General Structure of the Sympathetic and its Connections with the Cerebro-Spinal System.—Before passing to a detailed description of the various parts of the sympathetic system, a few general remarks anent the theories of the general structure of the sympathetic and the interrelation of its parts to the central nervous system by fibre tracts are necessary. The sympathetic nervous system contains fibres of centrifugal and centripetal function, that is, sensory fibres. The centrifugal function may be motor (viscero-motor or vaso-motor) secretory, trophic, or it may be inhibitory (viscero-inhibitory, vaso-inhibitory, secreto-inhibitory). This division of the centrifugal fibres into centrifugo-exciting and centrifugo-inhibiting fibres, may hold true also of the centripetal fibres; these are probably also centripeto-exciting and centripeto-inhibitory fibres. The centrifugal fibres must further be divided into at least two varieties, which distinguish themselves by their mode of origin.

(1).—*Cerebro-spinal motor*, (or more correctly, centrifugal) fibres, called also *motor fibres of the first order*, by Kölliker, and *preganglionic fibres* by Langley. (See Text-Figure 4). These fibres have their cells of origin in the spinal cord or cerebral axis, being in fact the axis-cylinders of such cells. These fibres condition the dependence of the cells of the sympathetic upon the cerebro-spinal system.

(2).—*Sympathetic motor* (or in general centrifugal) *fibres*, called also *motor fibres of the second order* (Kölliker) and *postganglionic fibres* (Langley). (See Text-Figure 4). These have their cells of origin in the ganglia of the sympathetic system, some in the ganglia of the two great gangliated cords, others in the prevertebral or peripheral plexuses. The fibres of the first named order terminate in end arborizations or pericellular nests around those nerve cells of the sympathetic ganglia or plexuses which give origin to fibres of the second order; in this manner the conduction of a motor impulse to the periphery is possible.

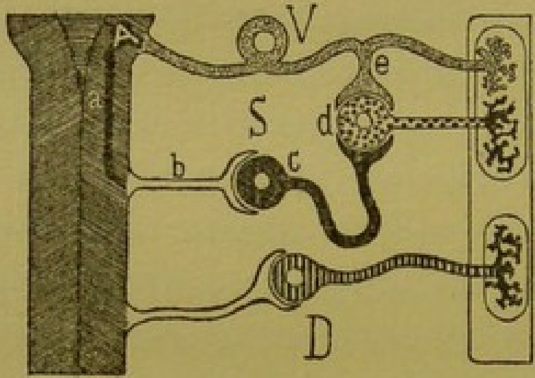
The existence of a third or fourth set of fibres is denied by Langley and Kölliker but claimed by Jendrassik. The former deny that the connection of the primary motor centre of the spinal cord or cerebral axis with the periphery is invariably established by more than two sets of neurons, which the latter claims. Recently Jendrassik has described a mode of termination of the peripheral sympathetic nerves which is so plausible in many respects that we shall make extensive reference to it. According to Jendrassik the sympathetic is divisible into two systems, the *spinal* and the *vagus systems*.

In the *first or spinal system*, following this investigator, most of the vegetative organs, perhaps all, have special ganglia embedded in their substance "vegetative organ-ganglia." These would correspond to the ganglia of the peripheral plexuses, the third general subdivision of the sympathetic in the preceding pages. As shown in the heart, when removed from the body, or by a piece of gut when resected, these ganglia may act independently to guide the motion or function of such organs. The organs are connected with the central nerve apparatus of the cerebro-spinal axis in this *first or spinal* by two, or rather three, pathways: 1.—By an emissive pathway, called the sympathetic system, the connection being mediated by three neurons: The first neuron passes from the cell of the spinal cord or brain through a ramus communicans to the ganglia of the gangliated cords

(Jendrassik calls these ganglia "vegetative central ganglia.") 2.—The second neuron passes from a cell of a ganglion of the gangliated cords to the "organ ganglia." 3.—The third neuron (corresponding to the fourth subdivision, the terminal or monocellular ganglia) passes from a cell of the "organ ganglion" to the organ itself. According to this writer, the purpose of the vegetative central ganglia is to receive the stimulus from the cerebro-spinal system and send the impulse to the cells of these "organ ganglia" whence it is sent to the terminus among cells of the viscus, *i. e.*, gland cell, intestinal villi.

The second connection between the organs and cerebro-spinal axis Jendrassik proposes to call the "*vagus system*," because the vagus is its chief representative. The vagus—he says—belongs morphologically to the sensory or centripetally conducting nerves. Jendrassik considers the vagus to be purely sensory and does not admit that any part of it is motor. The motor fibres that run with the vagus belong to other nerves. Only those fibres that originate from the ganglion jugulare vagi (analogous to the fibres from the spinal ganglia) and which establish a direct connection between the "organs" and the nuclei of the oblongata should be considered as vagus fibres. The fibres of the vagus (or of other fibres of the vagus system) send collaterals (Text-Figure 1, *e*) to the "organ ganglia" (*d*). Thus stimulation of the terminal arborization of the "vagus fibres" in the organ can influence the cells of the organ ganglion in a reflex manner (*e d*, Text-Figure 1). This illustrates the mechanism of a peripheral reflex arc, viz., from the terminus in the organ of a sensory vagus neuron centripetally to the collateral of this neuron to the organ ganglion neuron, centrifugally back to the organ again, the circuit *e d* in the diagram.

On the other hand there may be a more complicated reflex central circuit. This is established in the following way: The peripheral terminus of the sensory vagus neuron conveys the stimulus centripetally on the pathway *e V A* to the central vagus nucleus *A* then the stimulus enters the first segment *a* of the emissive pathway *A a b c d* passing then (after interruption by a cell of the spinal cord ?) via the ramus communicans *b* to the vegetative central ganglia *c*, thence through the second emissive segment, neuron *c*, to organ ganglion *d*, and finally the third segment of the emergent pathway back again to the organ. The circuit then would be represented on the diagram by the course *e V A a b c d.*



TEXT-FIGURE 1—JENDRASSIK'S DIAGRAM.

Explanation for Jendrassik's diagram (translated from the German explanations of the original text):

To the left the central nervous system in which *a* represents the central reflex pathway. At its upper end a central reflex centre *A*.

b=Motor root.
c=Cell of central ganglion (Centralganglienzelle).
d=Cell of organ ganglion (Organganglienzelle).
V=Vagus system.
D=Dilatator system.
S=Sympathetic system.

Jendrassik proceeds to explain the well known phenomena of the heart's action as the basis of the theory of these two pathways. For the details of this explanation we refer to his article.

A third kind of connection between the central nervous system and the organs is the so-called "dilatator system." This exists apparently for the iris, for Mueller's muscle, probably also for the glands and blood vessels and perhaps even for all motor and secretory elements. This innervation of the organs originates from the spinal cord and finds its way in the pathways of the sympathetic coming frequently from considerable distances. It is scarcely questionable that this connection becomes interrupted by nerve cells but it seems not to be influenced, or if so, to a very slight degree, in a reflex manner.

The duty of this system is to maintain a tonus acting antagonistically to the sympathetic system, (*i. e.*, in Jendrassik's motor system). It contains the dilator fibres of the iris and of the blood vessels. In these parts the system mentioned does not end in the same tissue elements as the other sympathetic fibres, but in the antagonists.

Jendrassik's ingenious theories do not have full justice done them by short quotations and we refer to his article for detailed information. We wish to call attention, however, to two weak points in his hypothesis, namely, to his contention of the purely sensory function of the vagus nerve, which we believe to be decidedly erroneous, and to his contention of the purely motor function of the sympathetic which is contradicted by the result of our researches.

According to Gaskell, most of the motor fibres of the rami communicantes are cerebro-spinal, those of the gray rami communicantes for the most part sympathetic. Nothing definite is yet known concerning the mode of origin of the sensory fibres of the sympathetic system nor of the manner of their connection with the cerebro-spinal system. Kölliker claims that all sensory fibres of the sympathetic originate from cells of the spinal ganglia in exactly the same manner as do the sensory fibres of the cerebro-spinal system. Dogiel, on the other hand, is inclined to assume the existence of specific sympathetic fibres derived from cells of sympathetic ganglia or plexuses. (See Text-Figure 4).

The two kinds of motor fibres, the cerebro-spinal and the sympathetic, are represented in nearly all subdivisions of the sympathetic system. Both kinds are met with in the rami communicantes, the white rami of which are for the most part composed of cerebro-spinal, the gray ones chiefly of sympathetic fibres (Gaskell). Many efferent rami contain predominantly sympathetic fibres; on the other hand, those efferent rami which proceed from the ganglia of the thoracic part of the sympathetic cord and unite to form the splanchnic nerves are said by Langley to be for the most part cerebro-spinal fibres, showing that they pass through the sympathetic ganglia of the thoracic portion without being interrupted by the cells of the latter. Cerebro-spinal fibres are found also in the more peripheral plexuses, intermingled with sympathetic fibres.

A word should be said here regarding inhibitory nerves. These may be of the efferent (analogous to motor nerves) or afferent order (analogous to sensory nerves) inasmuch as they can display their inhibitory influence on a given nerve cell, both in descending (towards the centrifugally terminal cells) and ascending (towards the same cell centripetally) direction. Such inhibitory nerves are of frequent occurrence. Indeed, wherever in the vegetative system one finds nerves performing motor, vasomotor, or secretory function, one also finds usually the antagonists, that is nerves inhibiting such functions. The inhibitory nerves have been encountered again and again by physiologists and for a long time their rôle was not understood. Gaskell however has given a very ingenious and plausible interpretation of their significance. In defining anabolism and catabolism he expresses himself as follows:

"There is, then, to my mind, no greater mystery involved in the conception of a nerve of *inhibition* than of a nerve of contraction. In the former case the cessation of function, the relaxation of tissue is the symptom of constructive chemical changes going on in the tissue, *i. e.*, the anabolism or assimilation or trophic action, in precisely the same way as the activity of function, namely, the contraction of tissue is a symptom of destructive changes, *i. e.*, catabolism or dissolution." Or by transcribing this we may say that the purpose of *inhibition* is the installation of restorative or constructive changes in the tissue, while function is the expression of opposite changes, *id est*, destructive or catabolic changes. It is evident, however, that the installation of restorative changes after function (or perhaps even during function) is indispensable for the resumption of function. The rôle of inhibition seen in this light clearly gains great importance for the muscular, glandular and other activities.

One of us (Onuf: A Tentative Explanation of some of the Phenomena of Inhibition on a Histo-physiological Basis, Including a Hypothesis Regarding the Function of the Pyramidal Tracts—*State Hospitals Bulletin*, 1897) has attempted to give an explanation of inhibition a histo-physiological basis and has called attention to the regulative rôle that inhibition may have on certain functions.

The theory may be expressed in word and diagram (Text-Figures 2, 3) as follows:

For the excitation of a nerve cell, the nerve current has to pass in the direction from the cell body or its protoplasmatic processes toward the nervous process; for the inhibition of the cell, the nerve current has to pass in the opposite direction, that is from the nerve process or its collaterals, back to the cell body. In other words, to produce excitation of a given cell, the nerve current must enter this cell from the surface of its cell body or of its dendrites; but in order to inhibit or moderate the action of the cell, the nerve current has to enter the cell from its nerve process or collaterals thereof.

These two modes of action are best illustrated by the diagrams Text-Figures Nos. 2 and 3. In both these diagrams the nerve processes have been drawn with red color, so as to distinguish them easily from the protoplasmatic processes. For both figures the same neuron A has been chosen. Text-Figure 2 shows this neuron A under the influence of excitation from the neurons B and C. Text-Figure 3 represents neuron A under the influence of inhibitory action from the neuron D.

Chapter II.

ANATOMY OF THE GANGLIATED CORDS.

We shall begin the detailed anatomical account with a description of: *The two great gangliated cords.*

It is customary to distinguish four parts or portions of the great gangliated cord: the cervical, the thoracic, the lumbar, and the sacral. We shall describe these in this order leaning our description on that given by Thane (Quain's Anatomy).

I.—*Cervical Part of the Gangliated Cord.*—In the neck the gangliated cord is placed deeply behind the great blood vessels of the neck, being embedded in the fascia which forms the posterior part of the carotid sheath. It

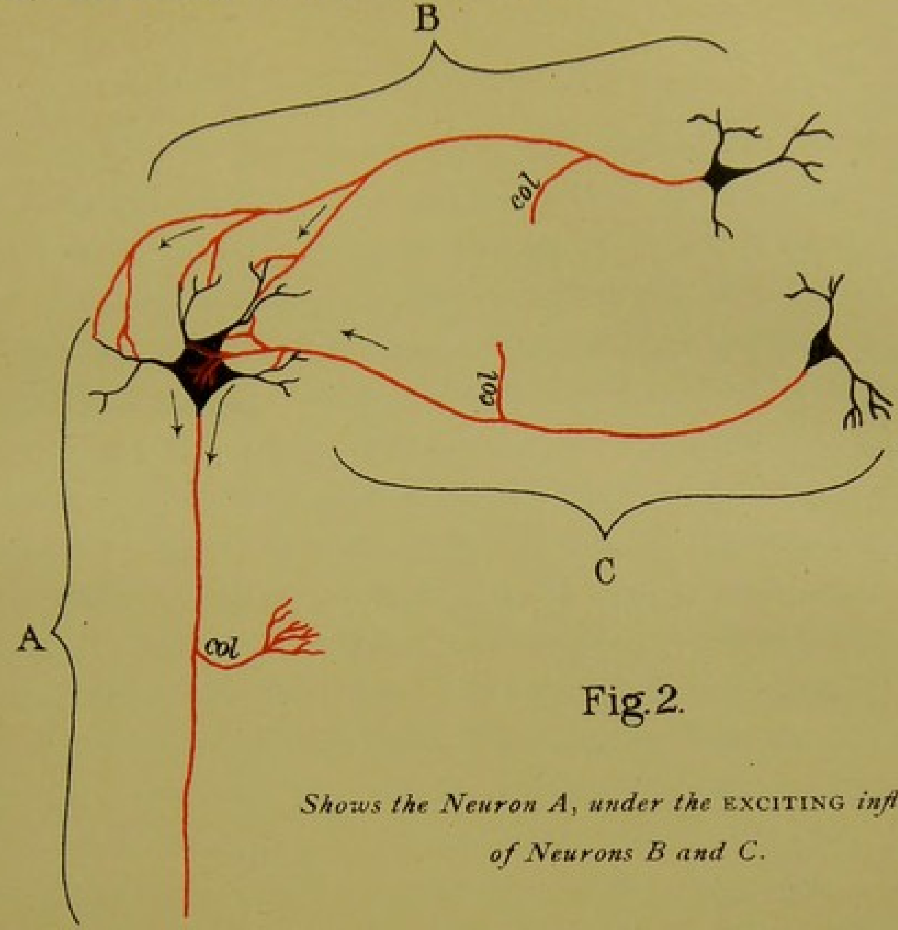


Fig. 2.

Shows the Neuron A, under the EXCITING *influence of Neurons B and C.*

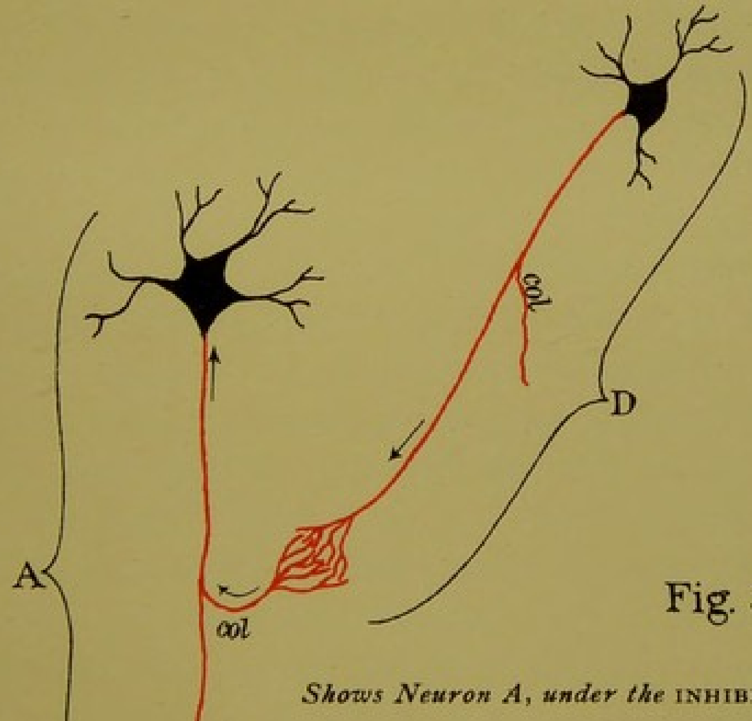


Fig. 3.

Shows Neuron A, under the INHIBITORY *influence of Neuron D.*

The direction of nerve current is indicated thus ⟶
The axones are colored red, the dendrons black.
Col = collateral.

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rests on those muscles which cover the anterior surface of the vertebral column. The cervical part of the gangliated cord consists of three ganglia, the first of which is placed near the base of the skull, the second in the lower part of the neck, and the third close to the head of the first rib.

1.—*Upper or Superior Cervical Ganglion.*—This is the largest ganglion in the great sympathetic cord. It is situated on the rectus anticus major muscle, opposite the second and third cervical vertebræ, behind the internal carotid artery, and to the inner side of the pneumogastric nerve. It continues above into an ascending branch and tapers below into the connective cord so that it usually has a fusiform shape, but in this there is considerable variation, the ganglion being occasionally short and broad, and sometimes constricted at intervals. We must now consider the various connections of this ganglion.

a.—Connection with Spinal Nerves.—At its outer side the superior cervical ganglion is connected with the first four spinal nerves by means of gray rami communicantes. The branches to the third and fourth cervical nerves often pierce the rectus anticus major muscle. They may be given off from the upper part of the cord instead of directly from the ganglion. Because this ganglion is connected with as many as four spinal nerves together with the fact that it is occasionally constricted, lends color to the view that it consists primarily of several ganglia which have coalesced. The superior cervical ganglion is considered by Gaskell to be a distal, or collateral ganglion. It receives its cerebro-spinal fibres, which constitute the cervical splanchnic of Gaskell, from the upper dorsal nerves to the cervical part of the sympathetic cord.

b.—Connection with Cranial Nerves.—Small twigs connect the ganglion or its cranial cord with the lower ganglion of the pneumogastric (ganglion cervicale vagi, plexus nodosus), and with the twelfth cranial nerve near the base of the skull. Another branch (n. jugularis) which is directed upwards from the ganglion, divides at the base of the skull into filaments, one of which ends in the petrosal ganglion of the glosso-pharyngeal nerve, while the others enter the jugular foramen to join the ganglion of the root of the pneumogastric.

Besides the branches connecting it with the cranial and spinal nerves the first cervical ganglion gives off other ascending branches, viz., pharyngeal branches, the upper carotid nerve, and branches to the blood vessels, as well as two or three filaments which pierce the prevertebral muscles to supply the upper cervical vertebræ and their ligaments.

c.—Ascending Branch and Cranial Plexuses.—The ascending or carotid branch of the first cervical ganglion (N. Caroticus internus) is soft in texture and of a reddish gray tint, being in some degree a prolongation of the ganglion itself. In its course to the skull, concealed by the internal carotid artery, it enters the carotid canal, in which it divides into two parts which are placed, one on the outer, the other on the inner side of the vessel.

The *external division* distributing filaments to the internal carotid artery, receives one or two carotico-tympanic twigs from the tympanic branch of the glosso-pharyngeal, and after communicating by means of other filaments with the internal division of the cord forms the carotid plexus.

The *internal division*, rather the smaller of the two, supplies filaments to the carotid artery and goes to form the cavernous plexus. The terminal parts of these divisions of the cranial cord are prolonged on the trunk of the internal carotid and extend to the cerebral and ophthalmic arteries around which they form secondary plexuses, those on the cerebral arteries ascending on the pia mater. One minute plexus enters the eyeball accompanying the central artery of the retina.

The *carotid plexus* (plexus caroticus internus) is situated on the outer side of the internal carotid artery at its second bend (reckoning from below) or between the second and third bends. It forms connections with the sixth nerve and with the Gasserian ganglion (the latter, however, occasionally receiving its supply from the cavernous plexus), gives off the large deep petrosal nerve which together with the large superficial petrosal from the facial, form the Vidian nerve, and so join the sphenopalatine ganglion. It further gives off the small deep petrosal nerve to the tympanic plexus, and supplies filaments to the internal carotid artery.

Cavernous Plexus.—This plexus, which takes its name from its position in the cavernous sinus, is placed below and slightly to the inner side of the highest turn of the internal carotid artery. Besides giving branches to the artery and all its branches: the ophthalmic, the anterior cerebral, the median cerebral and the posterior communicating arteries, and to the walls of the sinus, it communicates with the third, fourth, and the ophthalmic divisions of the fifth cranial nerves. The latter connection supplies filaments to the ophthalmic trunk (inner side) of the fifth nerve, and the sympathetic root to the ciliary ganglion. The cavernous plexus also furnishes minute filaments to the pituitary body.

d.—Pharyngeal Nerves and Plexus.—These nerves arise from the forepart of the first cervical ganglion and are directed obliquely inward to the side of the pharynx. Opposite the middle constrictor muscle they unite with branches of the pneumogastric and glossopharyngeal nerves, and by their union with these nerves the pharyngeal plexus is formed. Branches emanating from the plexus are distributed to the muscles and mucous membrane of the pharynx. One or two filaments pass from these branches to the superior and external laryngeal nerves.

e.—Laryngeal Branches.—These branches anastomose with twigs from the inferior laryngeal to form the so-called laryngeal plexus.

f.—Branches to Blood Vessels.—The nerves which ramify on the arteries (nn. carotici externi) spring from the front of the ganglion and twine around the trunk of the external carotid artery (plexus caroticus externus). They are also prolonged on the branches of the artery, forming upon them slender plexuses which are named after the arteries they accompany. From the plexus on the facial artery is derived the filament which forms the sympathetic root of the submaxillary ganglion, and from that on the middle meningeal artery twigs are described as extending to the otic ganglion, as well as to the geniculate ganglion of the facial nerve (external superficial petrosal nerve). One filament descends from these nerves to the parotid gland. Ganglia of microscopical size are frequently met with in the vascular plexuses, and several larger ones of more constant occurrence have been described, such for instance as the temporal ganglion.

g.—Upper (or superficial) Cardiac Nerve.—Each of the cervical ganglia of the sympathetic usually furnishes a cardiac branch, the three being named respectively, the upper, middle and lower cardiac nerves. These branches are continued singly or together, to the large prevertebral thoracic plexus (cardiac plexus) to the formation of which they contribute materially. Their size varies considerably, and when one branch is smaller than common, another will be found increased in size, as if to compensate for the shortcoming. There are some differences in the disposition of the nerves of the right and left sides, but in its course on the neck, the right upper cardiac nerve has relatively the same position and relations as the left one, being placed in the back of the carotid sheath.

2.—*Middle Cervical Ganglion.*—This ganglion, the smallest of the cervical ganglia, is placed on the sympathetic cord at or near the spot where it crosses the inferior thyroid artery, about opposite the sixth or seventh cervical vertebra. It is usually connected by gray branches with the fifth and sixth cervical spinal nerves, and with the superior and inferior cervical ganglia. It gives off thyroid branches which form the inferior thyroid plexus and the middle cardiac nerve. The latter in its course to the cardiac plexus gives off filaments to the recurrent branch of the pneumogastric, to the upper cardiac nerve, and to the thyroid branches of the middle cervical ganglia.

3.—*Lower or Inferior Cervical Ganglion.*—This ganglion is irregular in shape, usually somewhat flattened and round, or semilunar, and is frequently united to the first thoracic ganglion, the common mass being described as the first thoracic ganglion by many authors. It lies over the first costo-vertebral articulation in the lateral angle between the subclavian and vertebral arteries. The connecting cord between the middle and lower cervical ganglia usually passes behind the vertebral artery, but in some cases, especially on the left side, the interganglionic cord forms a ring around the vessel. The two ganglia are also united by the ansa subclavia (ansa Vieussenii). The latter name is given to a small cord, often double, which passes between the middle cervical and the lower cervical or first dorsal ganglion in front of the subclavian artery, or if double, forming a loop around that vessel, and supplying it with small offshoots (plexus subclavius). From the latter, filaments pass to the internal mammary artery and in some cases form a communication with the phrenic nerve.

The inferior cervical ganglion is connected with the lowest two cervical nerves by gray communicating branches. It gives off the lower cardiac nerve which passes behind the brachio-cephalic artery on the right and behind the transverse aorta on the left side. In addition it gives off shoots to the blood vessels. The latter ascend along the vertebral artery forming the vertebral plexus, the ultimate ramifications of which are continued on the intercranial branches of the vertebral and basilar arteries.

II.—*Thoracic Part of the Gangliated Cord.*—In the thorax the ganglia are placed on either side of the spinal column, in a line passing over the costo-vertebral articulations. They are covered by the pleura, and cross the intercostal blood vessels. The ganglia are usually eleven in number, seldom twelve. The first, when distinct is larger than the rest and lies at the vertebral extremity of the first intercostal space; but it is often blended with the lower cervical ganglion. The succeeding ganglia are small, oval, or triangular in shape, and in location correspond generally to the heads of the ribs, from the third to the eleventh, while the last is placed a little in front of the head of the twelfth rib, above the upper border of the last dorsal vertebra.

1.—*Rami Communicantes.*—The branches connecting the thoracic sympathetic ganglia with the anterior divisions (rami ventrales) of the dorsal nerves are usually two in number for each ganglion, one of these being white and the other gray.

2.—*Interfunicular Rami.*—Branches establishing a connection of the two thoracic sympathetic cords between each other are often found, but their occurrence is not constant.

3.—*Peripheral Branches of the Ganglia.*—The branches furnished by the upper four or five ganglia are small, and are distributed principally to the vertebræ and ligaments, and to the descending thoracic aorta, on which they form, together with filaments proceeding lower down from the gray splanchnic nerve, a slender network (plexus aorticus thoracalis). From the second, third and fourth ganglia offshoots pass also to the posterior pulmonary plexus, which is otherwise formed chiefly by ramifications of the pneumogastric nerve.

The branches furnished by the lower six or seven ganglia unite into three cords on either side, which pass down to join plexuses in the abdomen, and are distinguished as the great, the small, and the smallest, splanchnic nerves (abdominal splanchnics of Gaskell).

4.—*The Great Splanchnic Nerve.*—This nerve is formed by the union of roots which are given off by the thoracic ganglia from the fifth or sixth to the ninth or tenth inclusive. The trunk thus constituted descends mesially to the gangliated cord over the bodies of the dorsal vertebræ, and after perforating the crus of the diaphragm, terminates in the upper part of the semilunar ganglion; some of the fibres may occasionally be followed to the suprarenal body and the renal plexus. This nerve is remarkable from its white color and firmness, due to the fact that it consists in large part (four-fifths, according to

Ruediger), of medullated fibres, which are continued directly from the spinal nerves. They may be traced upwards from the highest root along the sympathetic cord as far as the third thoracic ganglion or nerve, or even higher. In the chest the great splanchnic nerve is not infrequently divided into parts and forms a plexus with the small splanchnic nerve. In many cases also a small ganglion (splanchnic ganglion) is formed on it. From the great splanchnic nerve and the splanchnic ganglion filaments are given to the front of the vertebræ and the aorta.

5.—*The Small Splanchnic Nerve.*—It arises from the ninth and tenth (sometimes the tenth and eleventh) thoracic ganglia, or from the neighboring part of the cord. It passes with the preceding nerve, through the diaphragm, or separately a little behind and to the right—and ends in the lower part of the semilunar (or in the aortico-renal) ganglion. In the chest this nerve often communicates with the smallest splanchnic nerve.

6.—*The Smallest Splanchnic Nerve.*—(n. renalis posterior of Walter). It arises from the last thoracic ganglion and communicates sometimes with the nerve last described. After passing the diaphragm, with the cord of the sympathetic, it ends in the renal plexus. Its place is frequently supplied by a branch of the small splanchnic nerve.

The three splanchnic nerves are composed for the most part of cerebro-spinal fibres.

III.—*Lumbar Part of the Gangliated Cord.*—In the lumbar region the two gangliated cords approximate one another more closely than in the thorax. They are placed on the front of the bodies of the vertebræ, each lying along the inner margin of the psoas muscle; that of the right side is partly covered by the vena cava, that of the left by the aorta. The ganglia are small and of oval shape. They are usually four in number, occasionally three or even two, and in such case they are of larger size.

1.—*Rami Communicantes.*—Because of the greater distance at which the lumbar ganglia are placed from the intervertebral foramina, the branches of connection with the spinal nerves are longer than in other parts of the gangliated cord. There are generally two connecting branches for each ganglion, but the number is not so uniform as it is in the chest, nor are those belonging to any one ganglion connected always with the same spinal nerve. The connecting branches accompany the lumbar arteries and as they cross the bodies of the vertebræ they are covered by the fibrous bands which give origin to the muscular fibres of the psoas.

2.—*Rami Interfuniculares.*—These are also inconstant in their occurrence, although more constant than in the thoracic part of the gangliated cords.

3.—*Peripheral Branches.*—They are inconstant in number. Some join the plexus on the aorta; others, descending, go to form the hypogastric plexus. Several filaments are distributed to the vertebræ and the ligaments connecting them.

IV.—*Sacral Part of the Gangliated Cord.*—Over the sacrum the gangliated cord of the sympathetic nerve is much diminished in size and gives but few branches to the viscera. It lies on the front of the sacrum along the inner side of the anterior sacral foramina and like the two series of these foramina, the right and left cords approach one another in their course downwards. The sacral ganglia are usually four in number; but variation, both in size and number is more common in these than in the thoracic or lumbar ganglia.

1.—*Rami Interfuniculares.*—Fine branches uniting the two cords are of constant occurrence here, especially at the lower end where they form a loop in which a single median ganglion, ganglion impar, or coccygeal ganglion, is often found. The interfunicular rami send off fine filaments into the vertebral bodies to the coccyx and the coccygeal gland.

2.—*Rami Communicantes.*—The branches connecting the sacral gangliated cord with the spinal (sacral) nerves are very short; there are often two for one ganglion, and these are in some cases connected with different sacral nerves. The coccygeal nerve communicates with the last sacral or the coccygeal ganglion.

3.—*Peripheral Branches.*—The branches proceeding from the sacral ganglia are much smaller than those from other ganglia of the cord. They are, for the most part, expended on the sacrum and join the corresponding branches from the opposite side. Some filaments from one or two of the upper ganglia enter the pelvic plexus, while others go to form a plexus on the middle sacral artery.

Chapter III.

THE ANATOMY OF THE PLEXUSES.

Under this head are included certain large plexuses of nerves placed further forward in the visceral cavity than the gangliated cords, which furnish branches to the viscera. The more important of these plexuses are the cardiac, the solar, and the hypogastric, with the pelvic plexuses prolonged from it. The plexuses are composed of assemblages of nerves or of nerves and ganglia, and from them smaller plexuses are derived.

I.—*Cardiac Plexus.*—This plexus is made up from the cardiac branches of the cervical ganglia and from numerous fibres of the pneumogastric nerves. From the plexus are derived the nerves which supply the heart, besides some offshoots which contribute to the nerve supply of the lungs. The cardiac plexus lies against the transverse aorta and pulmonary artery, where these vessels are in contact. It presents on the concave surface of the transverse aorta a large nerve ganglion known as the ganglion of Wrisberg. Two parts, the *superficial* and the *deep cardiac plexuses* are distinguished in its network. The deep plexus is principally behind the vessels, the superficial more in front, both being closely connected. Branches pass from these plexuses, chiefly forward, in two bundles, which accompany the coronary arteries and form:

(1).—The right or posterior coronary plexus.

(2).—The left or anterior coronary plexus. Filaments of these latter plexuses ramify under the pericardium.

Microscopical ganglia which might perhaps be classed among the peripheral plexuses (homologues of Auerbach's and Meissner's plexuses) in the walls of the intestine, (see page 8), occur in the nerves of the auricles, and in the course of the coronary plexuses. The ramifications of the latter give rise also to the terminal plexuses which Gerlach (quoted from Hoffmann and Rauber) has described as the "Grundplexus" and which, according to the recent investigations of v. Openchowski (quoted from Hoffmann and Rauber), give off terminal fibres to the muscular fibres. Van Gehuchten has observed by employment of the method of Golgi in the nerves of the heart of new born white mice a very abundant interlacing network between the nerve fibres of the muscle cells of the ventricle walls, but he has not been able to follow fibres of the peripheral ganglia. This same richness of fibres in every portion of the myocardium has been observed by Hymann and Demoor. The myocardial nerve filaments have also been beautifully demonstrated in the frog's heart by Strong.

II.—*Solar or Epigastric Plexus.*—The solar or epigastric plexus (plexus cœliacus) the largest of the three prevertebral plexuses is situated at the upper part of the abdomen behind the stomach, and in front of the aorta and the pillars of the diaphragm. Surrounding the origin of the cœliac and superior mesenteric arteries, it occupies the interval between the suprarenal bodies and extends downwards as far as the pancreas. This plexus consists of nervous cords, with several ganglia of various sizes connected with them. The large and small splanchnic nerves on both sides and some branches of the pneumogastric terminate in it. The branches given off from it are very numerous and accompany the arteries to the principal viscera of the abdomen, constituting many secondary plexuses on the vessels. Thus a diaphragmatic, cœliac, mesenteric and other plexuses are recognized. These accompany the branches given off from the upper part of the abdominal aorta respectively.

(1).—*Semilunar Ganglia*, (*solar ganglia*, *cœliac ganglia*, *abdominal brain*).—The solar plexus containing several ganglia is distinguished from other prevertebral plexuses by the size of these bodies. The two principal ganglionic masses (semilunar ganglia or solar ganglia, etc.) occupy the upper and outer part of the plexus, one on each side, and are placed close to the suprarenal bodies by the side of the cœliac and superior mesenteric arteries. At the upper end each ganglion receives the great splanchnic nerve. The lower part of the ganglionic mass lying over the root of the renal artery is usually more or less detached from the rest and is referred to as the *aortico-renal ganglion.* It is joined by the small splanchnic nerve and gives origin to the greater part of the renal plexus. Another part lying below and to the right of the origin of the superior mesenteric artery is named the *superior mesenteric ganglion.* The formation of the following plexuses is contributed to by the solar and other plexuses and by branches of the cerebro-spinal nerves.

(2).—*Diaphragmatic or Phrenic Plexus.*—This is situated at the lower surface of the diaphragm and is derived from the upper part of the semilunar ganglion. It is also supplied by the phrenic nerves. On the right side this plexus contains a ganglion which marks the junction of the phrenic (cerebro-spinal) and the sympathetic fibres. It gives filaments to the diaphragm, to the vena cava, to the suprarenal body and to the hepatic plexus.

(3).—*Suprarenal Plexus.*—The nerves to this plexus emanate from the solar plexus, chiefly from the outer part of the semilunar ganglion, but the plexus receives also some filaments from the diaphragmatic plexus and from one of the splanchnic nerves. It it is beset with minute ganglia.

(4).—*Renal Plexus.*—The chief supply is from the aortico-renal ganglion, but the solar and aortic plexuses, the smallest splanchnic nerve, and sometimes the small splanchnic nerve, as well as the first lumbar ganglion furnish also filaments. Ganglia of different sizes (renal ganglia) are met here. The plexuses of both sides give off twigs to the spermatic plexus and a filament to the urethra. The plexus of the right side supplies some filaments to the vena cava.

(5).—*Spermatic Plexus.*—This is derived for the most part from the renal plexus, and receives in addition some filaments from the aortic plexus. It follows the spermatic artery to the testes and frequently contains a small spermatic ganglion. It is distributed to the testicle and the epidermis. In the female the plexus accompanies the ovarian artery and is distributed to the ovary and uterus.

(6).—*Cœliac Plexus.*—This large plexus, derived from the solar surrounds the cœliac artery, situated in a kind of fenestrated sheath. It subdivides with the artery into stomachic, hepatic, and splenic plexuses, which following the respective blood vessels supply the stomach (coronary and pyloric plexuses), the liver (hepatic plexus), the gall bladder (cystic plexus, derived from the hepatic), the omentum (gastro-epiploic plexus, derived from the hepatic), the pancreas and duodenum (pancreatico-duodenal plexus, also chiefly from the hepatic), and the spleen (plexus splenicus, or lienalis). These plexuses anastomose with each other, with the mesenteric nerves, and with the suprarenal plexus. All of them receive additional supply from the pneumogastric nerve.

(7).—*Superior Mesenteric Plexus.*—This plexus, accompanying the superior mesenteric artery, is given off mainly from the lower part of the solar plexus and from the superior mesenteric ganglion. It receives fibres from the right pneumogastric at its junction with the cœliac plexus. Following the distribution of the superior mesenteric artery, this plexus divides into sub-plexuses which finally pass upon the intestine along the line of attachment of the mesentery. A large number of the filaments terminate between the two layers of the mesentery in so-called Pacinian corpuscles. These are cerebro-spinal fibres. In the wall of the intestine, the peripheral plexuses (Auerbach's and Meissner's) are formed.

(8).—*Aortic Plexus.*—The aortic or intermesenteric plexus (plexus aorticus abdominalis) placed along the abdominal aorta, chiefly in two lateral cords, is connected above with the semilunar ganglia and renal plexuses. It receives branches from some of the lumbar ganglia. Several filaments pass through the root of the inferior mesenteric artery to form the plexus on that vessel and in connection with these the inferior mesenteric ganglion, which is placed below the origin of the artery. The aortic plexus furnishes the inferior mesenteric plexus, as well as part of the spermatic; it gives some filaments to the inferior vena cava, and ends below in the hypogastric plexus.

(9).—*Inferior Mesenteric Plexus.*—This plexus, springing mainly from the left lateral part of the aortic plexus, clusters around the inferior mesenteric artery. It distributes nerves to the left or descending and the sigmoid colon, and assists in supplying the rectum. The highest branches (those on the colonic artery) are connected with the last branches (middle colonic) of the superior mesentery plexus, while others unite in the pelvis with offshoots derived from the pelvic plexus.

III.—*Hypogastric Plexus.*—The hypogastric plexus, destined for the supply of the viscera of the pelvis, is a flat plexiform mass, situated in front of the lowest lumbar vertebra, between the two common iliac arteries. It is formed by the prolongations of the aortic plexus on each side and receives a considerable supply of branches from the lumbar ganglia. At the lower end it divides into two parts which are directed downward to form the pelvic or inferior hypogastric plexuses.

The inferior hypogastric or pelvic plexuses, one on each side, are placed in the lower part of the pelvic cavity by the side of the rectum, and of the vagina in the female. After descending a short distance, they unite with branches of the spinal nerves, as well as with a few off-shoots of the sacral ganglia. The spinal branches which enter into the plexus are furnished from the third and fourth sacral nerves, sometimes also the second.

From the plexus so constituted numerous nerves are distributed to the pelvic viscera. They correspond in great measure with the branches of the internal iliac artery and vary with the sex; thus, besides hemorrhoidal and vesical nerves which are common to both sexes, there are nerves special to each, viz.: in the male, for the prostate, vesicula seminalis and vas deferens; in the female for the vagina, uterus, ovaries and Fallopian tubes. Accordingly the following plexuses can be distinguished.

1.—*Hemorrhoidal Plexus.*—These slender nerves proceed from the upper part of the pelvic plexus. They join with the nerves (superior hemorrhoidal) which descend with the inferior mesenteric artery and penetrate the coats of the rectum.

2.—*Vesical Plexus.*—The nerve plexuses of the bladder are continued from the lower part of the pelvic plexus and are placed chiefly on the lower surface of the bladder. Beside supplying the latter they furnish nerves to the vas deferens and to the seminal vesicles.

3.—*Prostatic Plexus.*—Situated between the prostate gland and the levator ani, this plexus supplies the prostate and the seminal vesicles. It is then continued forward to supply the erectile substance of the penis forming the nervi cavernosi or erigentes.

4.—*Vaginal Nerves.*—These nerves, derived from the lower part of the pelvic plexus, are distributed to the vagina without previously entering into a plexiform arrangement.

5.—*Nerves of the Uterus.*—They arise mainly from the lateral fasciculus prolonged to the pelvic plexus from the hypogastric plexus, with the addition of some filaments from the third and fourth sacral nerves. They form connections in the broad ligament with the ovarian nerves. Numerous small ganglia are contained in the plexus by the side of the neck of the uterus, and a cluster of them constitutes the ganglion cervicale of Frankenhäuser. They appear to be absent in the muscular substance of the organ.

Remarks on the Gross Anatomy of the Sympathetic Nervous System in the Cat.

The constitution of the sympathetic nervous system in the cat, although essentially homologous to that of man, presents some differences of arrangement that are worthy of note. In the first place the cat has thirteen dorsal and seven lumbar vertebræ, and in accordance with this the number of thoracic and lumbar sympathetic ganglia, or at least of the latter, is increased. On the other hand the cervical ganglia and the first (or more) thoracic ganglion are in the cat coalesced into one ganglionic mass to which the name stellate ganglion is given. This ganglion is situated between the first costo-vertebral articulations of the first and second ribs at the lateral border of the scalenus (posticus) muscle.

The stellate ganglion besides the communicating branches from dorsal nerves receives a very large, indeed, the largest ramus communicans from the pneumogastric nerve.

The stellate ganglion is physiologically as well as anatomically a compound ganglion, as it subserves the same functions which in man are fulfilled by the three cervical and the first thoracic ganglion. In view of the numerous physiological investigations on the nerve supply of the pelvic viscera, it is considered fitting to give some details of the structure and the relations of the inferior mesenteric ganglion in the cat. This ganglion consists of four small ganglia receiving their nerve supply:

(*a*) By one branch from the superior mesentric ganglion, and

(*b*) By three branches from the abdominal sympathetic nerve, known as the superior mesenteric nerve, the middle mesenteric nerve, and the inferior mesenteric nerve.

The inferior mesenteric ganglion gives off the hypogastric nerves, one for each side, which course with the hypogastric plexus (sympathetic supply). The latter receives additional supply on each side by a direct branch from the second, another from the third sacral nerves (Nawrocki and Skabitschewski).

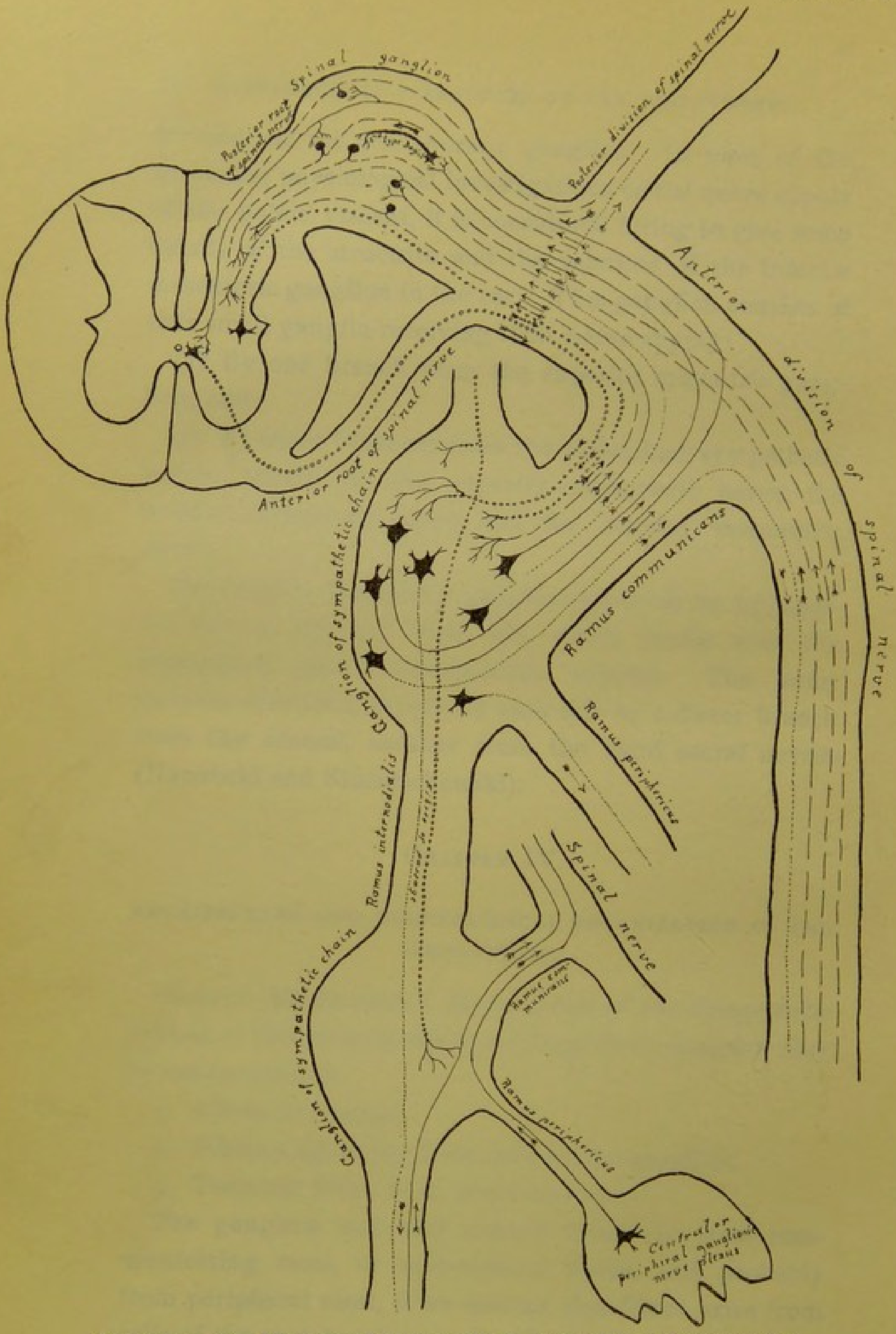
Chapter IV.

ARCHITECTURE AND MORPHOLOGICAL ORGANIZATION OF THE SYMPATHETIC.

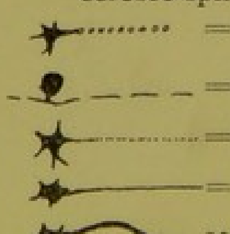
General Morphological Interrelation of the Sympathetic System.—The nerve fibres in a sympathetic ganglion may be enumerated as

1. Fibres of passage.
2. Fibres originating from cells of the ganglion.
3. Terminal fibres from other sources.

The ganglion may also contain collaterals from communicating rami, or commissural fibres, and probably from peripheral rami, if we assume that fibres arise from cells of the peripheral sympathetic ganglia.



TEXT FIG. 4.—Diagram of the structural interrelation between the cerebro-spinal and sympathetic systems.



=Cerebro-spinal neurons of centrifugal functions.

=Cerebro-spinal neurons of centripetal functions.

=Sympathetic neurons of centrifugal functions.

=Sympathetic neurons of centripetal functions.

Marked "2nd type Dogiel" in the figure = the Spinal ganglion cell of the second type of Dogiel.

All nerve fibres in passing through a sympathetic ganglion give off collateral branches which terminate by free ramifications between and around the cells which enter into the constitution of the ganglion. In every ganglion of the sympathetic chain there are found a number of fibres that terminate there. These may be longitudinal fibres belonging to the sympathetic chain, or peripheral (centripetal) fibres arising from nerve cells of peripheral ganglia and cerebro-spinal fibres conducted by the communicans ramus. (See Text-Figure 4). Many of those fibres that are continued as pale fibres, lose their medullary sheaths on joining with the cells of the ganglia; others pass through the proximate ganglion without relationship to the nerve cells (*fibres de passage*—see Text-Figure 4), and are continued toward the peripheral distribution as fine medullated fibres, but even these lose their sheaths in passing through the distal ganglia of the sympathetic system. All these terminal and lateral ramifications produce in the substance of each ganglion a most intricate interlacement of nerve fibrillæ enveloping the protoplasmatic prolongations and the bodies of the cells which make up the real ganglionic mass.

Fibres that come from the roots of the spinal nerves end in arborizations within the sympathetic ganglia. According to Ramon y Cajal, they form definite pericellular networks, but Lenhossek who inquired into this with great care has not been able to corroborate the occurrence of this pericellular network. These fibres that pass in from the spinal roots are some of them, unquestionably, motor (see Text-Figure 4) and take their origin according to Kölliker from cells of the spinal cord (denied by Dogiel).

Sala's Views.—Each sympathetic ganglion is traversed by bundles of nerve fibres in the ramus internodialis, in the ramus communicans or in the peripheral rami. Sala describes two types of fibres in a ganglion: 1. The varicose fibres, so-called because of the tortuosity in parts of their course, and 2. The dividing fibres, formed chiefly in the periphery of the ganglion. The varicose fibres are probably identical with Remak's fibres; they remain undivided. Many of them take their origin from the cells of the ganglion within which they are seen, while others take their origin in adjoining ganglia (fibres of passage), without entering into any connection with it, as they do not give off collaterals. The dividing fibres send off collaterals the ramifications of which constitute the diffuse network of the ganglion. Sala believes that the varicose, undivided fibres, are the real sympathetic fibres, *i. e.*, that they originate from cells of the sympathetic ganglia while the dividing fibres are in reality from the cerebro-spinal system.*

Gaskell's Degeneration and Excitation Experiments.—Even before the staining method of Golgi had revealed the wonderful interrelationship of the components of the nervous system, and before its general application to the study of the structure of the sympathetic nervous system, Gaskell had shown that fibres become interrupted by cells of the sympathetic ganglia. In the first place he had been struck by the fact that while the parts which connected a ganglion with the cerebro-spinal system were composed only of medullated fibres, the efferent rami of such ganglia contained non-medullated fibres. This meant that a transformation of medullated into non-medullated fibres took place in the ganglion. He found

* This is denied by Huber (Journal of Morphology, 1899, p. 27) who concludes as follows: "The observations above mentioned seemed to me to present very strong evidence in favor of the hypothesis long ago expressed by Ehrlich and Retzius that the spiral fibre was the ending of a cerebro-spinal fibre."

that in the healthy crocodile, if the vagus was cut above the ganglion trunci vagi, and the nerve stimulated peripherally at the cut end, that is above the ganglion, the stimulation caused a strong peristaltic contraction of the whole œsophagus extending through the cervical and thoracic portions into the stomach. The same effect took place when the nerve was stimulated below the ganglion. Gaskell then cut the vagus nerve above the ganglion and waited until it degenerated. Then when the nerve was stimulated above the ganglion the stimulation did not produce the slightest effect on any portion of the œsophagus or stomach. If the nerve was stimulated below the ganglion there was marked peristaltic contraction of the œsophagus and stomach but the cervical portion of the œsophagus remained absolutely quiescent.

These experiments of Gaskell proved that the fibres for the thoracic portion of the œsophagus are interrupted by the cells of the ganglion; owing to this interruption stimulation above the ganglion effected no contraction of the thoracic portion of the œsophagus, since all motor fibres above the ganglion were degenerated, while on stimulation below the ganglion the said portion of the œsophagus contracted. On the other hand the fibres for the cervical portion of the œsophagus were not interrupted by the cells of the ganglion. Therefore, as these fibres had degenerated there was no contraction of the œsophagus, it mattered not whether the nerve was stimulated above or below the ganglion because the fibres that pass into the ganglion from above had degenerated and as a consequence excitation of them caused no contraction.

Langley's Conclusions.—According to Langley, who based his conclusions upon the nicotine experiments quoted on p. 39, all the cerebro-spinal motor fibres that enter into the sympathetic nervous system, terminate in one or another sympathetic ganglion by establishing connection with the constituent cells of the ganglion. The axis cylinder prolongations of the centrifugal sympathetic fibres terminate in the muscular walls of the blood vessels, in the viscera or in the glands. The sympathetic ganglia are in reality the ending place of one set of neurons and the place of origin of a second set. Each ganglion of the sympathetic trunk is to be regarded as a primary centre apart from any connections with the spinal cord. The fibres which it sends off run in the main to the corresponding spinal nerve and follow the course of this nerve. These fibres emerging from the ganglion as a primary centre are connected with all the peripheral structures with which sympathetic fibres can be connected and which lie in their course, so that the function of the nerve fibres is determined by the structures in which they terminate and not by the nature of the nerve fibres. A nerve fibre proceeding from a sympathetic cell has no other sympathetic cell in its course (the cells of Meissner and Auerbach's plexuses are not considered by Langley to be types of sympathetic nerve cells). The fibres from the spinal cord to the sympathetic ganglion connect certain cells of the spinal cord with the cells of the sympathetic ganglia in the same way as the fibres of the pyramidal tract connect certain cells of the brain with the cells of the spinal cord. These spinal fibres become pilomotor, vasomotor, secretory, according as the fibres from the sympathetic with which they are connected end within the erector muscles of the hair, the muscles of the blood vessels or within the glands.

According to most physiologists all the axis cylinders that pass toward the periphery terminate in the viscera, muscles and glands. (Regarding inhibitory fibres, see pp. 14 to 16). The general rule, as accepted at least by the majority of investigators, is that the neurons are connected with each other only by contact and not by anastomosis, although Golgi still holds to the theory of anastomosis, and Dogiel is of a similar opinion. The direct course of the axone has been demonstrated by Langley for the pilomotor nerves of the cat by his well-known nicotine experiments. The injection or direct local application of a small dose of nicotine paralyzes the nerve cells of the sympathetic ganglia or the endings of cerebro-spinal fibres terminating around these cells; in this condition excitation of a ramus communicans precludes the cerebro-spinal fibres from causing any contraction in the muscles that erect the hair. On the other hand this contraction follows excitation of the peripheral sympathetic motor fibres. In this way he has shown that a given pilomotor nerve passes from cells of the individual ganglia of the sympathetic chain into the nearest communicans ramus, unites or associates itself with the corresponding ramus ventralis of the corresponding spinal nerve and then passes directly to the erectors of the hair of the animal's back. A similar arrangement can be shown to exist in the multipolar cells of the ciliary ganglion. The medullary fibres have been traced by Kölliker immediately into the eyeball through the ciliary nerve into the sphincter of the iris ending in the ciliary body. Langley has shown that the post-ganglionic sympathetic fibres course in a very similar way from their origin to their terminations in the intestinal walls, the liver, kidneys and other abdominal organs.

Jendrassik's ideas of the general organization of the sympathetic have already been mentioned. (See pp. 9 to 13).

The Morphological Organization of the Various Rami.

I.—Rami internodiales.

II.—Rami communicantes.

III.—Rami peripherales.

I.—*The Rami Internodiales.*—(See Text-Figure 4—ramus internodialis).—The fibres that are to be seen passing longitudinally from a ganglion into a ramus internodialis are the axis cylinder prolongations of nerve cells situated in the same ganglion or in an adjacent ganglion. In other words these rami internodiales or interganglionic longitudinal strands of the sympathetic are made up of vertical commissural fibres, coursing longitudinally through superimposed ganglia.

II.—*The Rami Communicantes.*—(See Text-Figure 4—ramus communicans).—In the rami communicantes are found both cerebro-spinal and sympathetic fibres. In other words these fibres represent the axis cylinder prolongations of nerve cells of the sympathetic ganglia, to pass to the spinal cord, while others are derived from the cerebro-spinal system, passing through a ganglion in order to terminate there or to find their way to a more peripheral ganglion. The rami communicantes are made up of fibres which average about 2.6 μ, or less, in diameter. Their function is to unite the spinal nerves to the chain of sympathetic ganglia. The communicans ramus, according to Gaskell, contains the splanchnic fibres of the spinal nerves and the sympathetic ganglia are its splanchnic or ventral ganglia. The rami are described as the white and gray.

The fibres of the *white rami* pass from both roots of the spinal nerves, principally from the anterior. It has been thought that all fibres that pass from the posterior roots are afferent, but Lenhossek has shown that in the chick the posterior roots contain fibres which spring from cells of the spinal cord and enter the sympathetic. (See Text-Figure 4.) Such fibres have not yet been seen in mammals. The white rami communicantes constitute alone the rami viscerales of the spinal nerves of the morphologists. According to Gaskell they are not furnished by all the spinal nerves. In the dog they are found only from the second dorsal to the second lumbar inclusive. In man it is probable that they exist from the first dorsal to the first or second lumbar nerves. As has before been stated the visceral branches of the second, third and fourth sacral nerves correspond to the white rami communicantes, although they do not join the sympathetic cord, but pass directly to the prevertebral plexuses.

The fibres of cerebro-spinal origin furnished by the rami communicantes of the ganglia of the sympathetic system are motor fibres destined to maintain the sympathetic nerve cells under the dependence of the cerebro-spinal system. These fibres terminate in part in the ganglia of the sympathetic chain in arborizations around the cells of the ganglion, and in part they pass directly into the peripheral nerves to terminate in peripheral ganglia, or they run for a variable distance upward or downward in the gangliated cord and pass by the rami efferentes to the prevertebral plexuses.

The *gray rami* communicantes are for the most part fibres destined for the periphery, although some of them are distributed to the vessels of the spinal cord and the nerve roots. The gray fibres arise principally from the cells of ganglion with which the branch is connected. Langley states that the gray fibres arising from the cells of one ganglion and running along the cord to leave by the gray ramus of the next ganglion, occur only exceptionally.

The fibres of peripheral origin, *i. e.*, from the cells of the ganglia on passing into the rami communicantes deport themselves according to Van Gehuchten in two ways: one set on arriving in the spinal ganglion turns back and helps to form the peripheral fibres of the peripheral spinal nerves. Of those passing centrally some go off in the posterior primary division of the nerve while others continue their course towards the cord to transmit to this segment of the cerebro-spinal axis the impressions received from the peripheral organs.

According to the researches of Cajal, the sympathetic fibres of the intermediary strand penetrate the spinal ganglia and terminate there in free ramifications around the body of the nerve cells. The sensory impressions received by the fibres of the sympathetic are thus transmitted to the cells of the spinal ganglia, that is to say, to the sensory elements of the cerebro-spinal system. Dogiel has obtained similar results. He distinguishes two types of nerve cells in the spinal ganglia and finds that it is around the cells of the "second" type that the processes of the sympathetic ganglion cells which enter the spinal ganglion, terminate. (See Text-Figure 4, second type Dogiel). Moreover, he is inclined to believe that the cells of the *second* type transfer to the *typical* spinal ganglion cells sensory impulses derived from the sympathetic system. In spite of the many investigations that have been undertaken to corroborate the findings of Cajal they have not yet been verified.

According to Lenhossek the axonal process of a sympathetic ganglion cell passes through the ganglion, enters into the ramus ventralis (the anterior division) of the spinal nerve from which it passes peripherally. Those fibres having a centripetal conduction are called sensory fibres. Van Gehuchten and other investigators state that nothing is known of their ulterior course. The former writer in discussing this matter recently said, "It seems to be established that none of them enter the spinal cord." We hope to prove that this statement is no longer justifiable and that it is very certain that some of them do enter the spinal cord.

In some animals, especially in the cat, the sympathetic nerve and its gray communicans rami contain a great number of medullated fibres which section of the spinal roots or severance of the posterior roots peripherally to the spinal ganglion causes to degenerate. This indicates that the trophic centre must be situated in the corresponding ganglion itself. Moreover, Langley has proven this to be the case by showing that section of the sympathetic nerve caused degeneration of these medullated fibres.

The Peripheral Rami (See Text-Figure 4, ramus periphericus).—The peripheral nerves of the sympathetic nervous system are made up of nerve fibres of two kinds: medullated and non-medullated (fibres of Remak). The non-medullated or fibres of Remak form the chief constituent of the sympathetic nerves. These nerves pass into the walls of the vessels, of the viscera, or into the glands of the intestinal and uro-genital system. The peripheral sympathetic nerves may be classified functionally into three kinds: motor, sensory and secretory, and probably a group of inhibitory fibres corresponds to each of these three groups.

The motor are destined to innervate the muscles of the vessels and the viscera. The motor fibres innervate also a certain number of striated muscles, such as the heart, the upper part of the œsophagus and the pharynx. The secretory fibres go to the glands of the intestine and the uro-genital system, to the sweat glands, the mucous glands, etc.

The sensory fibres terminate by free ramifications between the epithelial cells of the mucous membranes or in the depths of the walls of the viscera and the vessels, or between the formative elements of the glands. When they terminate between the two layers of the mesentery they constitute the Pacinian corpuscles.

Kölliker thinks that all the sensory fibres of the sympathetic system belong in reality to the cerebro-spinal system. Dogiel, on the contrary, it seems to us, has shown, that in the peripheral organs which are dependent on the sympathetic, there exist special nerve cells of sensory nature, whose protoplasmic prolongations terminate between the epithelial or endothelial cells and whose axis cylinders terminate centripetally in a sympathetic ganglion in order to make connection with the cell of origin of a motor fibre and constitute with this last a reflex nerve arc, as in the cerebro-spinal system.

The peripheral nerves of the sympathetic nervous system present a mode of distribution which is characteristic and which distinguishes them from the cerebro-spinal nerves proper. They have a remarkable tendency to unite, to interlace one with another and to form plexuses. The nodes of these plexuses, which are frequently of considerable size, constitute the peripheral ganglia. The nerve cells themselves are of the multipolar type, and they have innumerable protoplasmic prolongations, and one axis cylinder prolongation (van Gehuchten's researches on adult cat and dog).

Our knowledge of the internal organization of the sympathetic nervous system is still far from satisfactory. It is universally taught that the peripheral nerves are formed on the one hand from a number of centrifugally conducting fibres which represent the axis cylinder prolongations of the nerve cells of the ganglia of the sympathetic chain and the peripheral sympathetic ganglia, or supplied directly from the cerebro-spinal system by the communicant rami, and on the other hand of centripetally conducting fibres which represent, according to Dogiel, the axis cylinder prolongations of the nerve cells of the peripheral ganglia, or according to Kölliker, the peripheral prolongations of the cells of cerebro-spinal ganglia. The centrifugal fibres terminate by free ramifications in the peripheral organs such as is evidenced by the terminal ramifications which have been demonstrated in the vessel walls of the white mouse and the rat by Van Gehuchten, Kölliker and Retzius. The fibres of centripetal conduction terminate in the ganglia of the sympathetic chain and, according to Retzius by arborizations of the axis cylinders in the spinal ganglia.

Chapter V.

EMBRYOLOGY AND HISTOLOGY OF THE SYMPATHETIC.

Most embryologists believe that the sympathetic nervous system is formed, like other neural structures, from the epiblast. Formerly it was taught (Remak) that the sympathetic nervous system was mesodermal in origin, formed *in situ*. Recently Patterson has argued its mesodermal origin and development with much skill. He believes that the lateral sympathetic chain arises as a series of isolated points which ultimately become connected with the spinal nerves and with one another, and that the cervical and lumbar portions of the system are outgrowths of the lateral chain. Balfour regarded each sympathetic ganglion as an offshoot from a spinal nerve, and according to Onodi the sympathetic ganglia bud off from the spinal ganglia. Gradually these buds or offshoots become detached from the spinal ganglia until all epiblastic connection is severed, save the ramus communicans which afterwards unites them.

At the present day the trend of acceptable opinion seems to be in the direction of the development of the sympathetic system from the ectoderm, thus harmonizing itself genetically with other neural structures.

To prepare for the general consideration of the histology of the sympathetic we may recall the previous division of the following parts:

1.—*The ganglionic cord or trunk*, a series of ganglia united with each other by the rami internodiales (in the lumbar and sacral regions by the interfunicular rami additionally, uniting one gangliated cord with another) and with the cerebro-spinal nerves by means of the rami communicantes.

2.—The *intermediate or central nerve plexuses*, consisting essentially of the large prevertebral plexuses, and also the smaller plexuses, coronary, mesenteric, etc., most of which are in intimate connection with the prevertebral plexuses.

3.—The *peripheral plexuses* and the nerve fibres that go to the periphery: visceral, vascular and glandular.

4.—The *terminal monocellular ganglia.*

We can best refer to the histology of these structural components by dividing them into two groups and considering the components of the trunks or cords and ganglia in one group, and divisions 2, 3 and 4 in a second group.

The location of the sympathetic ganglia has been described. Their shape, structure, and constitution alone remain to be considered. Although the ganglia are variable in form and volume they present always the same internal structure which consists of a surrounding membrane of connective tissue, a supporting framework of the same material, of nerve fibres that pass through, on to and from the ganglia, and of nerve cells.*

Histology of the Cords and Ganglia.—The nerves of the sympathetic nervous system are of variable appearance, depending upon the relative amount of the medullated and non-medullated fibres entering into their constitution. Some of the nerves are white, others gray or grayish red in color. The white contain proportionately a large amount of fine white medullated fibres, the gray a comparatively slight amount. In some parts of the sympathetic nerves the white and gray fibres run along for a considerable distance without blending, but usually after the white fasciculi have passed through one or more ganglia the two sets of fibres become thoroughly mixed. The white fibres are about one-half the size of the gray and measure from 2.5 μ to 3.3 μ in diameter.

Formerly it was thought that the nerve cells that entered into the constitution of the sympathetic ganglia were of different shapes and types; later that all the cells were multipolar and that each prolongation of these multipolar cells became an axis cylinder process. Neither of these statements is true. In mammalia the cells of the sympathetic ganglia are, as a rule, multipolar, but each process of a cell does not become an axis cylinder process. On the contrary the great majority of them are protoplasmic. (Lenhossek has shown that in fish the cells are bipolar, in amphibia they are unipolar).

* The terminology is in many places not in strict accordance with the neuron doctrine; we can only plead the fact that the exposition of the structure of the sympathetic on the neuron basis is still obscure and makes the older fashioned though inexact nomenclature permissible.

The type of cells entering into the constitution of the sympathetic ganglia forms a very important distinction between mammalia and fishes and vertebrates; it furnishes a point of distinction between the sympathetic and spinal ganglia in each class. In the mammalia the cells are multipolar, in the fishes and amphibia they are unipolar or bipolar. Retzius has used this fact to great advantage in allotting certain ganglia of the cephalic extremity, previously considered as belonging to the cerebro-spinal nerves, to their proper class.

The ganglia themselves are surrounded by a thin, firm, adherent covering of connective tissue which sends prolongations through the ganglion and divides it into compartments of different sizes and shapes. The individuality of these compartments is obscured by the fibre constituents of the ganglion. In Plate I, Figure 1, is shown very well indeed the pericellular capsule, (cps.) a membrane in which nuclei are imbedded, at definite intervals. It is taught by some histologists (Schultze), that this transparent capsule is continuous with the primitive sheaths of the nerve fibres. On careful examination it is seen to consist of flat epithelial-like cells, and contains a certain amount of connective tissue probably the same as that entering into the formation of the compartments of the ganglion. The nuclei embedded in the membrane are to be seen with great distinctness in the illustration. The specimen from which it was made was subjected to double staining; first the entire ganglion was stained in carmine, then embedded in paraffine and stained according to the Pal modification of the Weigert hematoxylin method. On account of this double staining not alone the medullated, but also the non-medullated constitutents, are colored and show distinctly. The medullated fibres (*med.*) appear as heavy black strands; the non-medullated (*non*) as reddish brown fibres, (Plate I, Figure 1). The bundles of medullated fibres go predominantly toward the middle of the ganglion where they undergo brush-like division. In the centre of the ganglion are seen bundles of medullated and non-medullated fibres, while toward the periphery the fibres are almost exclusively of the latter variety (fibres of Remak). Delicate bundles of these non-medullated fibres are seen passing between the constituent cells of the ganglia, particularly toward the periphery.

The cells of the sympathetic ganglia are on the average smaller, less numerous, and stain less deeply with ordinary dyes (*e. g.* carmine) than cells of the cranial and spinal nerve ganglia. When seen *en masse* they are fairly round; when seen singly, of very irregular contour. The average diameter of these cells is about 20μ, although some of them may be only 13μ while others are as large as 40μ. The cells do not seem to have any definite disposition or relationship in the ganglion and the peripheral cells have no distinguishing feature save that of color, perhaps, which allows one to differentiate them from the central cells. In some instances the peripheral cells are collected into more or less isolated groups by the sheath that extends into the ganglion, and this gives an appearance which has been thought by some writers to be quite characteristic.

Golgi's method of metallic impregnation* shows the outline of the multipolar cells with great distinctness and the

* We refer here also to the beautiful results obtained by Huber (Journal of Morphology, 1899, page 27) with the methylene blue "in vivo" stain in the sympathetic ganglia of different classes of vertebrates. His fine researches, splendidly illustrated, give especially valuable information on the structure and constitution of the pericellular network formed by terminating nerve fibres.

Nissl method of methylene blue shows the constitution of the cells. The technique of the latter method of staining the cells of the sympathetic nervous system requires in order to obtain satisfactory results, much practice, but when it succeeds, it shows the structure of the cells most admirably. The sections must remain longer in the staining fluid, before differentiation, than sections from other parts of nervous system. If the stain is a satisfactory one, on first sight it appears as if the chromophile part of the cell substance was composed of coarse plaques, but closer examination shows that these apparently coarse plaques consist of a conglomeration of granules (Plate I, Fig. 2). Aside from certain morphological conditions these coloring agents show that the constitution of the cells of the sympathetic ganglia do not differ materially from other nerve cells of the cerebrospinal system, insomuch as each cell has many protoplasmic processes of longer or shorter course that terminate not far distant from the cells of their origin and a nervous process (axone) which goes to form a constituent of a peripheral ramus, a ramus internodialis, or of a ramus communicans. (Text-Figure 4.)

The variation in form and extent of the dendritic processes of the multipolar cells of the sympathetic ganglia is considerable. In some dendrites the terminal ramifications are very numerous, and cluster in the shape of a basket forming a pericellular network around other cells. Others terminate very simply and free, each one of the dendrites having a number of nodes or varicosities developed upon it. When the protoplasmatic processes terminate freely among the cells of the ganglion their ulterior ramifications are very fine and it is difficult to distinguish them from the termination in the ganglion of the nerve fibres that enter and end there. Ramon y Cajal has studied carefully the terminals of the dendrites and has described the pericellular meshwork around other cells. He is inclined to the belief that these clusters are of great significance in explaining the functional interrelationship of the cells. Kölliker, on the other hand, says, that after mature deliberation he cannot believe that they have any physiological significance. Van Gehuchten thinks the arrangement is accidental and has not the importance which Cajal attributes to it. Contrary to this last investigator, Dogiel assumes that all cells of a ganglion are associated by means of a network formed by the dendritic processes. Some of these processes reach even into the next ganglion.

Histology of the Plexuses and the Monocellular Ganglia.—The ganglia of the cœliac and hypogastric plexuses, the ophthalmic and spheno-palatine ganglia, and probably the ganglia of the heart, are of a similar constitution to the ganglia of the great sympathetic chain. According to Ramon y Cajal the cells have a fibre of Remak, or an axis cylinder prolongation, which leaves the ganglion to join a ramus communicans or to form a peripheral branch passing to the organ which it supplies; and in addition there are the protoplasmatic prolongations which end near the cells of their origin within the ganglion itself.

The peripheral (visceral ganglia of Cajal) *i. e.*, the ganglia of the intestines, the bladder, the œsophagus, etc., are composed of small multipolar cells, the expansions of which, after extensive ramifications, pass into the plexuses which terminate either in non-striated muscular fibres or in glandular cells. In addition to these they contain, according to Cajal, fibres of passage which are possibly the continuation of fibres from the grand sympathetic chain and collaterals which end between the nerve cells.

He believes that there are no anastomoses between the visceral ganglia, the fibres of passage nor the collaterals of the visceral ganglia. Cajal describes small monocellular ganglia which are found in the interstices of the glandular tissue or in the intestines within the villi; such are the interstitial nerve cells of the glands of Lieberkühn, the nerve cells of the pancreas and those of the salivary glands. He calls these cells interstitial ganglia in contrast with the ganglia of the order of Auerbach's and Meissner's plexuses which he refers to as visceral ganglia, properly called.

Each gland, and perhaps each group of non-striated muscular fibres, no matter how small it may be, contains interstitial nerve cells, the expansions of which help to build up the plexus formed by the visceral ganglia and the fibres of the grand sympathetic nerve.

PART II.

THE PHYSIOLOGY OF THE SYMPATHETIC.

CHAPTER VI.

GENERAL FACTS AND FUNCTIONAL CLASSIFICATION.

The earliest experimental investigations on the function of the sympathetic system date back as far as the beginning of the eighteenth century. According to Claude Bernard's statement, Pourfour du Petit was the first to experiment upon the sympathetic nerve. In 1727 the latter published a monograph in which he asserted to have demonstrated, experimentally, that severance of the cervical sympathetic causes contraction of the pupil and sinking in of the eyeball. Since that time the subject has been taken up by a host of authors, chief of whom we may mention Claude Bernard, Schiff, Vulpian, Dastre and Morat, Luchsinger, Heidenhain, Gaskell, and Langley.

After collecting all the facts known regarding the functions of the sympathetic system, it may safely be concluded that it has, to a great extent, a controlling influence over the secretion of most of the glands, the lachrymal, the salivary, the sweat glands, the glands of the stomach and intestines, the liver, the kidney, etc.; that it presides over circulation by regulating the calibre of the blood vessels and the action of the heart; that it influences respiration; and, finally, that all involuntary muscles, those of the digestive apparatus, of the genito-urinary system, of the hair follicles (pilomotor nerves) are under its control. To show how far the involuntary muscles may be independent of the cerebro-spinal nervous system, we may cite the fact that in certain mammalians the bladder still continues to fulfill its function for weeks after all the cerebro-spinal motor nerves leading to it have been severed. In short, we find that all vegetative life of the organism is, to a more or less extent, under the control of the sympathetic system. Therefore, we are justified in calling it the vegetative nerve system *par excellence*. Whether it may also be called the trophic nervous system, we do not dare to assert, although many facts speak unequivocally in favor of this view. We shall instance only that according to Heidenhain the parotid gland undergoes very marked morphological and instantaneous changes under the influence of excitation of the sympathetic, while the intense activity of this gland produced by excitation of the cerebral secretory nerve does not lead to any perceptible changes of its structure.*

* See foot-note, page 63.

In discussing the processes which are said to be under the influence of the sympathetic system, we shall subdivide the subject as indicated in the chapters of Part II, viz.:

1.—Secretory influence:
- *a.* Lachrymal gland.
- *b.* Sweat glands.
- *c.* Mammary glands.
- *d.* Glands of the digestive apparatus.
  1. Salivary glands.
  2. Glands of the stomach and intestine.
  3. Liver.
  4. Pancreas.
- *e.* Kidney.
- *f.* Glycosuria.

2.—Vascular functions.

3.—Cardiac functions.

4.—Respiratory functions.

5.—Influence upon involuntary automatic motions.
- *a.* Stomach and intestines.
- *b.* Bladder.
- *c.* Uterus, etc.
- *d.* Pilomotor nerves
- *e.* Pupil.

6.—Trophic and tonic functions.

7.—Reflex action of the sympathetic.

8.—Functional interrelation of cerebro-spinal and sympathetic systems.

Our researches gave us opportunity of making some physiological observations. Instead of reporting them *en bloc*, we shall, for convenience sake, add them singly to the facts gathered from the literature on the same subject in the corresponding chapters.

Chapter VII.

SECRETORY FUNCTIONS.*

The sympathetic system has been proven to exert its influence on the secretion of the lachrymal glands, of the glands of the stomach and intestine, including the pancreas, of the salivary glands, of the sweat glands, and on the secretion of bile and urine. We shall mention here for convenience sake, although not really coming under this heading, the relation of certain lesions of the sympathetic to the production of glycosuria.

I.—*Lachrymal Secretion.*—According to Demtschenko and Wolferz, excitation of the sympathetic nerve of the neck (in cats) causes lachrymal secretion. This secretion is too copious to be explained by mechanical compression of the lachrymal gland and by protrusion of the eyeball as caused by excitation of the sympathetic nerve. The sympathetic lachrymal secretion differs physically from the trigeminal secretion; for the former is cloudy and the latter clear and transparent. Bechterew and Mislawski confirm this statement of the influence of the cervical sympathetic nerve upon lachrymal secretion. They find, moreover, that both the cerebral cortex (internal parts of

* Matthews ('97) has recently given the mechanism of secretion a careful experimental study and his conclusions are of such vital interest that no one can afford to neglect them in discussing the physiology of secretion. We give these conclusions in his own wording:

"There is no single mechanism of secretion. In some glands the stored metabolic products are driven out of the cells by the action of muscle, as in Amphibian skin glands and sudoriferous glands; in others they are removed by currents of lymph, which are probably the result of osmosis, as in the pancreas, stomach, salivary glands; in some cases the cells imbibe water until they burst and their contents rush into the gland lumen, as in the intestinal cells of Ptychoptera larvæ; in others the inner end of the cell crumbles to pieces, as in the mammalian milk glands. Two or more of these mechanisms may coexist in one gland, and it is this which has rendered the physiology of such glands as the salivary so confusing. Whether secretory nerves exist or whether secretion is ever a function of the gland cell must be considered at present an open question."

the anterior and posterior portion of the sigmoid convolutions) and the thalamus (circumscribed spot in the depth of its internal part at the level of the anterior portion of the gray commissure) preside over lachrymal secretion by way of the fifth nerve, partly also by way of the cervical sympathetic.

From our own experiments on three cats from each of which we removed one stellate ganglion, the following facts were noted: In one of the cats (three and a half months old) an injection of one centigramme of pilocarpine, given three weeks after the operation, produced lachrymal secretion of the eye of the normal side while the eye of the operated side remained dry. In the second cat (about two months old) five milligrammes of pilocarpine were injected one month after the removal of the left stellate ganglion. In this case the result was altogether different: Both eyes wept, but the eye of the operated side more profusely than the other. About an hour after the injection there was still considerable lachrymal secretion from the eye of the operated side, while the other eye was dry. In the third cat (about six weeks old) an instillation of a two per cent solution of pilocarpine was made in both eyes, four and one-half months after the operation. The effect was an equal amount of lachrymal secretion in both eyes.

These results are rather contradictory, and further experimentation must be made to harmonize them and to allow of a correct interpretation. It must be taken into consideration, of course, that the age of the animals varied, as did also the period (after the operation) at which the pilocarpine was administered. The manner of administration of the poison was different also.

II.—*Sweat Secretion.*—That sweat secretion is under the control of the nervous system cannot be doubted by any one at present. It has been claimed by some, however, that the nerves do not act upon the secretion directly, but upon the circulation; in other words by vascular influence. In refutation of this view, Luchsinger, who has studied the question very carefully, produces forcible arguments, proving beyond doubt, that sweat secretion is dependent upon direct nerve influence and has not direct causal connection with the state of circulation, as it may take place irrespective of such state.*

According to Vulpian, the sweat glands are, like the salivary glands, subject to antagonistic influences, both of which are effects of the tonic activity of certain parts of the nervous system and which are enacted by two different kinds of fibres: the secretion-exciting (fibres excito-sudorales) and the secretion-moderating fibres. The subject has not been followed up, however, and the physiological facts which have come to our knowledge concern only the sweat-exciting fibres.

Whether any sweat secretory fibres leave the spinal cord by way of the posterior roots, has never been debated. It is generally assumed that only the anterior spinal roots contain sweat secretory fibres. The statements that have been made as to their further course are very diverse. So far as we have been able to determine, all authors admit that part of the fibres pass through the great gangliated cords before joining the peripheral nerves, and some writers (Nawrocki and Luchsinger, and Langley) go so far as to say that all sweat fibres destined for the limbs are derived *indirectly*, *i. e.*, through intermediation of the sympathetic nerve, from the spinal

* According to Matthews' researches, the sweat glands, like the salivary glands, receive a double nerve supply and probably possess a double mechanism of secretion, *i. e.*, a muscular and an osmotic. See also foot-note, p. 55.

cord. Vulpian opposed this view, claiming that if one abdominal sympathetic nerve was severed at the level of the fourth lumbar vertebra, sweat secretion could still be produced in the hind paw of the same side, which could only be the case if part of the sweat fibres joined the peripheral nerves (sciatic) directly, without connection with the gangliated cord. Luchsinger then called attention to the fact that Vulpian in his experiments severed the abdominal sympathetic at such a high level (fourth lumbar vertebra) that not all sweat fibres contained in the sympathetic were severed by the section.

To meet every objection, Luchsinger repeated his own experiments. He extirpated the whole abdominal sympathetic nerve of one side in eighteen cats and then studied the effects of heat on the hind paws of the animal. In sixteen of the eighteen cats he found his former conclusions confirmed. But the remaining two cases were exceptions to the rule inasmuch as in spite of the extirpation of the abdominal sympathetic nerve the hind paw of the same side could still be made to sweat. Regarding the sweat fibres for the fore paws, views have been equally divided; Vulpian, claiming on the one hand that part of the sweat fibres went directly from the spinal cord to the brachial plexus, Luchsinger, and lately Langley, contending on the other hand that all sweat fibres for the fore paw enter the thoracic sympathetic and pass through the stellate ganglion before joining the nerves of the brachial plexus.

The outcome of three of our experiments makes it very doubtful whether all sweat fibres for the fore paw pass through the sympathetic nerve or at least through the stellate ganglion, although any other course within the sympathetic except through the stellate ganglion seems excluded. In two cats we extirpated the left stellate ganglion, in a third the right stellate ganglion. Twenty-five days after extirpation (the wound had healed by primary union) a hypodermatic injection of one centigramme of pilocarpine was made in one of these animals. Ten minutes after the injection, the right fore paw was dark, the skin soft, and showed numerous sweat drops. The left fore paw (operated side) was pale, dry, and showed not the least trace of sweat. An hour after the injection, the difference was much less marked; the left fore paw had become darker, evidently from being somewhat soaked, but no sweat drops were seen, while the right fore paw still showed sweat beads very distinctly.

Luchsinger has called attention to the fact that if the sweat fibres are severed two weeks or even longer before the sweat secretion is tested, in other words at a time when the fibres have not undergone complete degeneration, a so-called retarded secretion is occasionally observed, which manifests itself by the length of time that elapses before the secretion takes place (on the application of heat, for instance). When, however, the degeneration of the nerve fibres is complete, the sweat secretion is entirely absent.

We felt inclined to assume that such a condition of retarded secretion was present in our case and that the moistening of the fore paw of the operated side which was found one hour after the pilocarpine injection could be interpreted in accordance with Luchsinger's views, in other words that it was an effect of excitation of the incompletely degenerated sweat fibres. Observation of a second and third animal, however, taught us that this view was incorrect. In these two cases the administration of the pilocarpine was made three, and four and one-half months, respectively, after the extirpation of the stellate ganglion, in one case by hypodermic injection, in the other by instillation into the eyes. The time that elapsed between the removal of the ganglion and the pilocarpine tests was so long in both cases that it would be unwarrantable to assume that the fibres had not entirely degenerated. In one of these two cases (removal of the left stellate ganglion), the result of the pilocarpine test, made three months after the operation, was as follows:

5-10 minutes after the injection:—Both fore paws covered with sweat, the right more than the left, yet the sweat secretion is very distinct in the left fore paw. Here the epidermis is moist, dark, softened, and numerous sweat drops are seen. The left hind paw sweats a trifle less than the right one.

One hour and fifteen minutes after injection:—All paws are still sweating; the left fore paw still shows distinct sweat drops, within one or two minutes after it has been wiped off. The right fore paw sweats more intensely. The left hind paw sweats now no less than the right one.

Six hours after the injection:—All paws still somewhat moist. The animal was killed the next day, and the post-mortem examination showed a complete absence of the left stellate ganglion, and of the thoracic sympathetic nerve down to the second intercostal space.

In the other (third) animal, instillation of a few drops of a 2% pilocarpine solution into each eye produced sweating of all paws, apparently no less of the fore paw of the side (right) on which the stellate ganglion had been removed four and one-half months previously.

This evidence seemed to warrant the assertion that not all sweat secretory fibres of the fore paw pass through the stellate ganglion and through the main trunk of the sympathetic in general, but that a good portion of them follow other pathways, and that these fibres develop compensatory functions so strongly as to entirely mask the loss of function. But yet we had to note the paradoxical fact, that when on a later occasion we began the etherization of cat No. 2, in order to perform another operation, *the struggles of the animal against being etherized produced considerable sweating of all paws except the left fore paw which remained perfectly dry.*

In order to harmonize these apparently contradictory facts two explanations are possible.

First. Not all sweat fibres for the fore paw of the cat pass through the stellate ganglion. Nevertheless those which do not pass through this ganglion are in the minority and cannot entirely compensate for the loss of sweat secretory function taking place in the fore paw when by removal of the stellate ganglion of the same side the sweat fibres passing through this ganglion are destroyed. Hence loss of a stellate ganglion would make it difficult to start sweat secretion in the fore paw of the same side but when once started it would become almost as abundant as in the other limbs.

The second explanation, perhaps even more plausible than the first, is, that the pilocarpine acts mainly on the peripheral nerve apparatus, perhaps on the interstitial nerve cells of the sweat glands mentioned by Ramon y Cajal, and that this peripheral nerve apparatus is to a considerable degree independent and does not degenerate when the nerves controlling them are destroyed. If this was so, and if indeed *all* sweat fibres for the fore paw passed through the stellate ganglion as Luchsinger and Langley claim, the loss of this ganglion would have the following influence upon the sweat secretion in the fore paw of the same side: Pilocarpine would still retain its effect and cause sweat secretion in that paw, but any sweat secretion depending for its enactment upon an unbroken nerve connection of the sweat glands with the cerebro-spinal centres—such sort of secretion as took place when one of our operated animals began to sweat owing to its struggles against the etherization—would become impossible.

We regret not having tried the action of heat on the sweat secretion but at the time we had no proper facilities for such tests.

For the sweat glands of the head even Luchsinger admits both a sympathetic (fibres of the cervical sympathetic nerve) and a direct non-sympathetic nerve supply, the latter being furnished either by the spinal cord or the oblongata. Luchsinger emphasizes the view, however, that the cervical sympathetic nerve is the principal sweat nerve for the head. (In pigs and cattle certain glands of the muzzle of cattle are the homologa of sweat glands).

III.—*Lacteal Secretion.*—Of the special influence of the nerves upon the mammary glands and upon the secretion of milk, we know only that while erection of the nipple is impossible when the spinal nerves which supply the breasts are divided, the secretion continues and is not arrested even when the sympathetic as well as the spinal nerves are severed (Foster).

IV.—*Secretion of the Glands of the Digestive Apparatus.* —1.—*Salivary Secretion.**—von Wittich and Nawrocki first observed that secretion of the parotid gland occurs not only by influence of cerebral nerve fibres, but also of the sympathetic nerve of the neck. von Wittich further noticed that electrical excitation of the cervical sympathetic nerve remained without effect upon secretion of the parotid gland, if the facial nerve of the same side had been torn out from the cranial cavity either immediately or some days before, showing that in their course toward the

* Claude Bernard's observations on the submaxillary gland and ganglion are referred to under the heading "Tonic Influence."

gland the secretory fibres of the cervical sympathetic become connected with the facial nerve.

Jaenicke claims that the sympathetic nerve causes secretion of saliva only by its vasomotor function, and that it has no real secretion-promoting or secretion-inhibiting fibres.

Eckhard also expresses doubts as to whether the sympathetic nerve directly governs the process of secretion of the parotid gland.

Heidenhain made microscopical examination of the gland in the state of rest and in the state of activity produced by excitation either of the sympathetic or the cerebral fibres, and came to the following very interesting conclusions:* The secretion obtained by excitation of the sympathetic nerve (in dogs or rabbits) is very scarce. It is very improbable that physiologically the sympathetic nerve has an actual secretory influence upon the parotid gland; yet the excitation of the nerve has a powerful effect upon this organ. If the excitation takes place

* In the light of Matthews' investigations Heidenhain's theories and the generally accepted trophic nerve mechanism of secretion are very questionable. Matthews has arrived at the following conclusions regarding salivary secretion:

(1).—"The sympathetic nerve induces salivary secretion by acting on contractile tissue in the glands and thus causing a compression of ducts and alveoli."

(2).—"The chorda tympani, or other dilator salivary secretory nerve probably causes secretion by its dilator action on the blood vessels, thus increasing osmosis."

(3).—"The evidence that the chorda tympani acts on the gland cells is open to serious objections, as follows:"

(*a*).—"Atropine probably acts directly on the gland cells and capillary endothelium, diminishing their permeability."

(*b*).—"The post-mortem chorda salivary secretion is possibly due to a back flow of blood from the veins owing to a dilation of the capillaries."

(*c*).—"The increased content of organic matter in a secretion coincident with an increased rate of secretion is of little value as evidence of secretory nerves, because," (1) "saliva is generally not a true solution, and (2) a weak stimulus probably arouses but a portion of the gland."

(*d*).—"The evidence derived from the action of nicotine and the degenerated chorda tympani that secretion may ensue on stimulation of the chorda without vaso-dilation is of doubtful value, because of an erroneous method of determining that vaso-dilation has not occurred."

shortly before or simultaneously with the excitation of the cerebral secretory fibres (nervus Jacobsoni) the composition of the secretion is changed. The percentage of organic, especially of albuminous substances, becomes increased in a high degree. To explain this effect which takes place quite independently of the vasomotor function of the sympathetic nerve, we must assume that the latter acts more through trophic than through secretory function upon the parotid. And, indeed, the following facts corroborate this view: When the parotid gland is thrown into an intense activity by the cerebral secretory nerve so that it secretes from 12 to 13 cubic centimetres of saliva, the secretion scarcely differs in its microscopical appearance from that of the gland in a state of rest. If, on the other hand, it has secreted from two to three cubic centimetres of saliva, under the influence of the sympathetic nerve, the character of the cells is changed to such a degree that one thinks he has to deal with a completely new organ.

Langley has repeated Heidenhain's experiments and has studied the gland microscopically in the fresh (living) state. He found that under influence of excitation of the trophic fibres the number of granula seen in the protoplasm of the cells increased considerably while it diminished under the influence of the true secretory fibres. Langley found, however, that *in the cat the trophic fibres are not contained in the cervical sympathetic*, *but*, *on the contrary*, *in what is considered the cerebro-spinal-secretory nerve*, *viz.*, *in the chorda tympani.*

2.—*The Glands of the Stomach and Intestine.**—Contejean in experimenting upon frogs found that the pneumogastric nerve has a stimulating influence upon the secretion of gastric juice, the sympathetic having but little effect in

* See also foot-note, page 55.

this direction. From the fact that these animals can still live from four to six days after all connections of the stomach, with the exception of the mesentery deprived of its nerves were severed, and that the secretion of the gastric juice continues during that time, Contejean concludes that the centres presiding over the secretion of gastric juice are situated in the intra-stomachal plexuses. The pneumogastric and sympathetic nerves have a regulatory influence upon the secretion of the stomach glands.

Moreau made similar observations on the secretion of the intestinal glands. If a piece of an intestine was separated from the rest of the gut by two ligatures and all nerves of the mesentery leading to it were severed, this isolated piece of gut filled itself with an apparently abnormal secretion fluid.

The influence of special nerves upon the secretion of intestinal juice has not been studied as yet. It is therefore appropriate to record our own observations in regard to this subject. We found that disturbance of digestion followed the removal of the stellate ganglion and of the lower thoracic portion of the sympathetic cord, and also the removal of a semilunar ganglion. The digestive disturbances following extirpation of the stellate ganglion were, however, more marked and more persistent than those noted after removal of the lower thoracic sympathetic. They consisted of diarrhœa and of putrefaction of the fæces. The fæcal matter was semi-consistent, of yellow or dark grayish brown color and of exceedingly foul odor.

This putrefaction of the fæces was observed in two of the three animals from which we removed the stellate ganglion. In the third cat they were not noted, but it should be added that this cat was killed before a time corresponding to that which had elapsed antecedent to the occurrence of putrefaction in the first two cats. The putrefactive symptoms made their appearance as late as two and three months after the operation, and it was noted that the digestive disturbances had a tendency to increase, and persisted until the death of the animals, three, and four and one-half months, respectively, after the operation. In one instance, the autopsy revealed marked anæmia of the intestines.

After section of the lower part of the thoracic sympathetic nerve, performed in two cats, (6th to 9th, 8th to 11th thoracic ganglia, including the adjoining piece of the splanchnic nerve) we observed two temporary attacks of diarrhœa of a few days' duration in one case. In the other cat no symptoms were observed on the part of the digestive tract, but this animal was killed as early as four weeks after the operation. Vomiting was observed occasionally, both after removal of the stellate ganglion and of the lower part of the thoracic sympathetic, but this symptom was very inconstant and transitory.

In two cats, aged five and a half weeks and two months respectively, one semilunar ganglion was removed. Both animals withstood the operation very well and at first were very playful, but two weeks after the operation cat No. 1 (three and one-half weeks old) began to develop diarrhœa, which, however, disappeared after a few days. Three weeks after the operation the animal began to be uncertain in gait which increased to well-marked staggering, and to have diarrhœa. Within two days it died in collapse. The other animal was allowed to live only three weeks, and during this time it had no diarrhœa. During the last five days it had vomiting attacks, but nevertheless was very playful, and probably it would have lived for several days, even weeks, had it not been killed.

From the fact that the intestinal disturbances, especially the putrefaction of the fæces, were very much more marked after removal of the stellate ganglion than after resection of the lower part of the thoracic sympathetic, including the adjoining piece of the splanchnic nerve, we conclude that the pneumogastric nerve has a stronger influence than the splanchnic nerve upon the stomachal and intestinal functions. Incidentally, we may mention that this conclusion is in harmony with the results obtained by Contejean on the stomach of frogs. It should be added here by way of explanation, that in the cat the stellate ganglion receives a very strong communicant branch from the vagus nerve.

The tendency of the symptoms to increase is most plausibly explained by a degeneration progressing toward the periphery and affecting finally the intra-stomachal and intra-intestinal plexuses. This tendency was noted in every case, and again we emphasize that these symptoms appeared weeks or even months after the operation, and not immediately. They appeared earlier in the cats which had had their semilunar ganglia removed. This harmonizes with the explanation just given.

3.—*Secretion of the Bile.*—Munk observed that excitation of the splanchnic nerve in rabbits was followed first by an acceleration, then by a retardation of the flow of bile. He attributes this effect chiefly to vasomotor influence and to stimulation of the muscles of the gall ducts. The latter effect was also noted by Doyon (quoted from Howell) who states that the corresponding nerve fibres reach the liver through the semilunar plexus.

Afanassiew noted that section of the nerves of the liver gave rise to a polycholia: (*a*) increased secretion of bile; (*b*) dilatation of all the blood vessels of the liver to a marked degree and afterwards dilatation of the lymphatic pathways; (*c*) excess of urobilin, its presence being caused partly by the polycholia and partly by compression of the fine gall ducts by the dilated blood and lymph vessels, the consequence being retention of bile; (*d*) absence of glycogen in the liver; (*e*) swelling of the liver cells, which take on an appearance similar to that observed after fibrin feeding.

Howell concludes that as far as our knowledge goes, the physiological evidence is against the existence of true secretory nerves controlling the formation of bile. On the other hand, he says, there are some experiments (Morat and Dufour), though not absolutely conclusive, which indicate that glycogen formation within the liver cells is influenced by a special set of glyco-secretory fibres.

4.—*Influence upon the Pancreatic Secretion.**—According to the investigations of Pawlow and his students (quoted from Howell) stimulation of the vagus nerve or the sympathetic causes, after a considerable period of latency, a marked flow of pancreatic secretion. Howell says that in accepting the theory of trophic and secretory fibres, the experiment seemed to indicate that trophic fibres are more abundant in the sympathetic, and similarly, the secretory fibres proper in the pneumogastric.

V.—*Renal Secretion.*—Howell concludes that the majority of purely physiological experiments upon direct stimulation of the nerves going to the kidney are adverse to the theory of secretory fibres, the marked effects obtained in these experiments being entirely explicable by the changes produced in the blood supply of the organ. Hermann comes to similar conclusions.

The vascular nerve fibres to the kidney are supplied

* See foot-note, page 55.

by the renal plexus and are preponderatingly but not exclusively derived from the splanchnic nerves (Hermann). According to Bradford the innervation of the vessels of the kidney is furnished by the anterior roots of the dorsal nerves from the fourth downwards and of the lumbar nerves down to the third and fourth; most abundantly, however, by the eleventh, twelfth and thirteenth dorsal. The existence of fibres passing within the splanchnic to the kidney exerting a tonic influence cannot be proven (Hermann). According to Langley and Dickinson the splanchnic vascular fibres of the kidney are interrupted by cells of the renal plexus.

Peyrani has found that section of the cervical sympathetic causes a lessening of the quantity of urea and urine to a minimum, while excitation of the peripheral (head) stump of this nerve causes an increase both of urea and urine. Kuelz could not confirm these results and denies that the cervical sympathetic has any influence upon the above-mentioned secretions.

VI.—*Glycosuria produced by Influence of the Sympathetic.*—Although not belonging to the secretions proper, we find it convenient to refer to the subject of glycosuria here.

Since Claude Bernard showed that irritation of the floor of the fourth ventricle, the so-called hepatic vasomotor centre or area causes glycosuria, physiological and pathological evidence has been accumulated to show that the production of grape sugar stands in causal relationship to the function of the sympathetic nervous system. Schiff demonstrated that section of the vasomotor pathways in the spinal cord at any level down as far as the exit of the nerves for the liver caused glycosuria. Pavey noted that destruction of the superior cervical ganglion caused glycosuria, and Eckhard observed that a similar condition resulted when the inferior cervical and first thoracic were destroyed. Trambusti showed experimentally that after extirpation of the cœliac plexus there was deposition of glycogen in the kidneys. Nearly every physiologist who has experimented on the abdominal sympathetic and afterward carefully observed the constitution of the urine, has found that lesion of this part of the sympathetic is accompanied usually by glycosuria (Klebs, Munk, Hensen).

The hypotheses that have been advanced to explain the occurrence of glycosuria with these experimental lesions of the sympathetic nervous system are numerous. The majority of writers seem to be of the opinion that the occurrence of grape sugar with such lesion is immediately conditioned by change in the tonus of the blood vessels of the liver and in the quantity of blood passing through the liver. These hypotheses have been the less convincing because of our ignorance of the chemico-physiological genesis of glycogen and grape sugar.

From our own experience we have noted, that resection of the lower part of the thoracic sympathetic (sixth to ninth or eighth to eleventh thoracic ganglia) was followed by diabetes. The urine was examined in two cases directly after the death of the animal. In one cat in which we removed the sixth, seventh, eighth, and ninth thoracic ganglia and which was killed four weeks after the operation, we noted: "No albumen, but a slight amount of sugar." In a second cat (resection of the lower thoracic including the eighth, ninth, tenth, and eleventh ganglia) which was killed four months after the operation, we found: "No albumen, but a large amount of sugar." (Fehling's test applied in both cases).

Considering the large amount of sugar found four months after the lesion of the thoracic sympathetic, we may conclude that the glycosuria caused by such lesions is not temporary but permanent and seems to have a tendency to increase rather than to diminish, as far as we can judge from two cases. We regret that in other cats, especially those in which extirpation of the stellate ganglion was done, the sugar test was omitted.

We find then, that nearly all secretory glands are under the influence of the sympathetic nervous system. The facts indicate, as Claude Bernard stated for the submaxillary ganglion and gland, that there is independence and dependence of action of the peripheral (that is, sympathetic) secretory nerve apparatus from the central nervous system. The fibres of the latter (cerebro-spinal fibres, motor fibres of the first order—Kölliker; preganglionic fibres—Langley) exert a controlling influence upon the secretions, which influence is either stimulating or inhibitory; purely secretory, or partly vascular; or solely vascular, as in the case of the kidney for instance, where the existence of purely secretory fibres could not be proven. For some glands (salivary, pancreas) the existence of true trophic nerves is highly probable* and it would seem that most of the trophic fibres are derived from the sympathetic cord.

Chapter VIII.

VASCULAR FUNCTIONS.

The investigations of Claude Bernard, Dastre and Morat, Ostroumoff, Gruetzner, Heidenhain, and others, have demonstrated the existence of two kinds of vascular nerve fibres (fibres colorifiques of Claude Bernard). The excitation of one kind causes vaso-constriction: "vaso-motor

* Matthews' conclusions render this questionable.

or vaso-constrictor fibres;" while excitation of the other kind produces vaso-dilatation; "vaso-dilator or vaso-inhibitory fibres." The vaso-constrictor fibres usually predominate in number or strength, and are therefore easier demonstrated than the vaso-dilators. To prove the existence of the latter, special experiments have to be made. Ostroumoff succeeded in exciting the vaso-dilators of the lower extremity by employing single induction beats at intervals of five seconds. Morat used very strong tetanizing currents in order to demonstrate vaso-dilator fibres in the posterior roots of spinal nerves. Dastre and Morat, although able to produce vaso-dilatation of the bucco-facial region in dogs directly, by excitation of the peripheral stump of the cervical sympathetic nerve after section of the latter, could not produce such effect in cats or rabbits. In these animals, however, they succeeded in obtaining vaso-dilatation of the face and lips by reflex action from sensory nerves.

The effect of excitation of nerve fibres upon the blood vessels can be noted either by direct inspection as in the blood vessels of the ear for instance, or by measuring the temperature of the parts containing the blood vessels by means of metal-thermometric needles (Heidenhain, Gruetzner), or by measuring the blood pressure in the parts concerned.

So much for motor vascular nerves. As to sensory nerve supply, Spallita and Consiglio find that the entire vascular surface is provided with special sensibility, capable of producing notable modifications in the general distribution of the blood. It is the opinion of these investigators that the function of the vaso-sensitive nerves is to prevent a superabundance of blood in the peripheral parts of the circulatory system, an action analogous to that which Cyon admitted for the sensory nerves of the heart and of the liver.

The relation which the motor vascular nerves bear to the sympathetic has been studied by Claude Bernard, Ostroumoff, Gruetzner and Heidenhain, Langley, and others. The vascular fibres leave the spinal cord for the most part with the anterior roots; but a part of the vaso-dilator (vaso-inhibitory) fibres are contained in the posterior roots (Stricker, Gaertner, Morat). In their further course the vascular fibres either join the great gangliated cord by means of communicant rami, which is the case for most if not all vascular fibres of the limbs (Claude Bernard, Ostroumoff, Heidenhain and Gruetzner, Langley), or they pass from the spinal nerve directly to one of the great prevertebral plexuses. We find, thus, for instance, that part of the vascular fibres supplying the pelvic viscera are derived from the lumbar plexus and join the periphery by intermediation of the great gangliated cord, while the other part, arising from the sacral nerves, pass directly to the hypogastric plexus without connection with the gangliated cord (Langley).

Many of the vascular fibres enter the gangliated cord and become interrupted by cells of the ganglia of the latter. This is probably the case with most of the vaso-dilator and vaso-inhibitory fibres for the limbs. Others again, those which are contained in the posterior roots, are said to be interrupted by cells of the spinal ganglia (Morat). Still others take an uninterrupted course through the sympathetic cords, using the latter only as a kind of commissure. This has been demonstrated to be so for the vascular fibres of the splanchnic nerve which pass without interruption from the spinal cord either to the semilunar or to the superior mesenteric ganglion (Langley and Dickinson).

The presence of both vaso-constrictor and of vaso-dilator fibres has been proven in almost every division of the sympathetic system. The presence of the constrictor nerves is easier to demonstrate, as a rule, but the existence of vaso-dilator fibres has been shown in the cervical sympathetic nerve (Dastre and Morat, for the ear and bucco-facial region; Cavazzani, for the brain) in the abdominal and thoracic portions of the sympathetic cord (Ostroumoff, Gruetzner and Heidenhain, for the hind paws; Langley, for the hind paws and fore paws; Hallion and Fr. Frank, for the intestine), and in the hypogastric plexus (Langley, for the pelvic viscera).

In closing this chapter, we wish to record that in two cases of extirpation of one stellate ganglion we measured the temperature of the fore paws six days and three weeks after the operation, respectively. The temperature was taken in the "wrist" joint by flexing the paw upon the "forearm," so as to bring the latter into intimate contact with the paw.

In the cat whose temperature was measured six days after the removal of the ganglion the result was: Left fore paw, (operated side) temperature 100.4° F. Right fore paw, temperature 99.2° F. For comparison, the temperature was measured also in the axilla, and 100.8° F. was found on each side. In the second cat the temperature was measured three weeks after the operation, with the following result: Left fore paw, (operated side) temperature 102° F. Right fore paw, temperature 100.6° F. We see therefore that the vaso-dilatation in the fore paw produced by the removal of the stellate ganglion was still present in a marked degree three weeks after the operation. Whether it gradually diminishes afterwards, or remains permanent, we did not determine.

Chapter IX.

CARDIAC FUNCTIONS.

The striking autonomy of the peripheral nerve apparatus of the heart is shown by the fact that the latter when removed from the body, or deprived of all the nerves passing to it, still continues to beat for some time, in cold blooded animals even for days. Yet its action is under the control of certain nerves, part of which have an accelerating and at the same time an augmenting (intensifying) influence, augmentor nerves,—while the others have an inhibitory effect by lessening the number of beats and the force of the contractions: inhibitory nerves of the heart.

Most of the inhibitory nerves are contained in the pneumogastric nerve which is the cardiac inhibitory nerve *par excellence.*

In the dog the augmentor fibres are said to leave the spinal cord by the anterior roots of the second and third and to some extent the first and fourth, possibly the fifth thoracic nerves. They travel by the several rami communicantes to the stellate ganglion and pass thence to the cardiac plexuses and to the heart by nerves from the ganglion itself or from the ansa Vieussenii, or from the so-called lower cervical ganglion. In the cat the path of the augmentor impulses is very similar and we may regard the statement just made as representing in a broad way the pathway of impulses in mammals generally. They leave the spinal cord by the upper thoracic nerves and pass to the heart through the lower cervical and upper thoracic sympathetic ganglia (Langley, Foster).

Part of the augmentor fibres however, are derived from the pneumogastric nerve (Hermann). Schiff, who goes so far as to claim that the pneumogastric alone contains augmentor fibres, says that when this nerve is completely degenerated no acceleration of the heart action can be obtained through any nerve. He concludes that the influence which the sympathetic ganglia has upon the acceleration of the heart's action, is due to the action of the pneumogastric nerve connected with them.

We feel more inclined to accept Langley's statement of the course of the majority of the augmentor nerves—through the communicant rami of the upper dorsal nerves.

Chapter X.

RESPIRATORY FUNCTIONS.

Graham finds that the splanchnic nerve has a reflectory, inhibitory influence upon respiration. If the splanchnic nerve of the one (left) side is severed and the central stump excited by the faradic current the respiration arrests itself in the state of expiration—diaphragm perfectly relaxed, abdominal muscles contracted. The tests succeed also when both pneumogastric nerves were severed at the neck.

Section of the oblongata above the region of the respiratory centre does not influence the result, which remains also unchanged when the spinal cord is severed between the eleventh and twelfth dorsal vertebræ, while the excitation of the splanchnic nerve loses its effect if the section is made between the fourth and fifth dorsal vertebræ. This shows that the fibres in question enter from the splanchnic nerve into the spinal cord above the eleventh or twelfth dorsal, and below the fourth or fifth dorsal vertebræ, and then ascend to the oblongata to influence the respiratory centre.

Guillebeau and Luchsinger confirm Graham's observation of the influence of faradic excitation of the splanchnic nerve upon respiration if the spinal cord is intact; but if the oblongata is severed from the cord the effect of the faradization of the splanchnic nerve is contraction, not only of the abdominal muscles but of the diaphragm. They contend that the spinal cord contains the primary centres for abdominal *pressure* (Bauchpresse) because after isolation from the oblongata the mechanics of the abdominal pressure can be brought into action reflectorily by excitation of sensory nerves.

We are able to add some observations concerning the effect of lesions of the sympathetic upon respiration. These effects deserve so much more attention because they did not as a rule make their appearance immediately, but weeks after the operation. In our report we shall include all disturbances of the respiratory act, as well as perversion of the secretion of the mucous glands of the respiratory tract. It will be most convenient to give a concise history of each case.

Experiment No. 1.—Removal of the left stellate ganglion in a cat aged from three to four months. Animal killed twenty-five days after the operation.

In the second and third weeks after the operation the following symptoms set in and remained, with about the same intensity, until the animal was killed:

Purulent secretion from the nose and occasional attacks of sneezing. Aside from this the animal has paroxysms which resemble singultus more than cough, although it is difficult to make a definite differentiation. When the animal is dozing or asleep it is free from these paroxysms but they reappear when it awakes and begins to move about and usually persist until the cat falls asleep.

Post-mortem examination showed miliary tuberculosis of the heart and pericardium.

Experiment No. 2.—Removal of the left stellate ganglion in a cat aged about two months. Animal killed three months after the injury.

Two days after the operation the cat began to have sneezing fits. About a week afterwards a mucous, later a purulent discharge from the nose developed. These symptoms continued until the death of the animal. Four weeks after the removal of the ganglion the animal began to have attacks of cough and hiccough, chiefly when astir, less when lying still. These paroxysms are less frequent than the sneezing attacks. Mucous discharge from the eyes.

About five weeks after the operation the breathing became labored, difficult but slow; it was audible at some distance by a wheezing sound comparable to the rhonchi heard in chronic bronchitis. In the further course the breathing—with exacerbations and remissions—retained the whistling asthmatic or bronchitic character being worse when the cat was asleep. The spontaneous paroxysms of cough and hiccough gradually disappeared, but when the animal (while awake) was stroked over the larynx for some time, it was taken with attacks resembling whooping-cough. These attacks lasted for one or two minutes or longer.

The autopsy showed the lungs much congested, of a red dark brown color, with lobular infiltration in the lower lobes and compensatory emphysema.

Experiment No. 3.—Extirpation of the right stellate ganglion in a cat six weeks old. Animal killed four and one-half months after the experiment.

One week after the operation it was noted that the cat began to have sneezing attacks which, however, disappeared in the course of three weeks. Otherwise there were no respiratory symptoms.

Experiment No. 4.—Resection of the lower part of the right thoracic sympathetic nerve (eighth, ninth, tenth, eleventh thoracic ganglia, including the adjoining splanch-

nic nerve) in a cat of about five weeks. Animal sacrificed five and one-half months after the experiment.

Two months after the operation the cat began to have coughing fits whenever it is stroked on the back until it purrs. The attacks cease very soon when the stroking is discontinued, to reappear again when the stroking is resumed.

Four months after the operation the animal commenced to have rather intense spontaneous attacks of hiccough and coughing. These were less severe, however, than in cat No. 2. The attacks keep on with rather increased than lessened frequency until death.

Post-mortem examination reveals an absolutely healthy appearance of the lungs.

Experiment No. 5.—Resection of the right thoracic sympathetic nerve (sixth to ninth thoracic ganglia including adjoining splanchnic) in a cat of five to six weeks. Animal sacrificed four weeks after the operation.

No symptoms appear in this case. We must not forget, however, that in animal No. 4 the symptoms began as late as two months after the operation.

Autopsy reveals speckled appearance of the lungs, due evidently to pigmentation. They appeared normal otherwise.

We see, thus, that the defect of one stellate ganglion as well as the lower part of the sympathetic (including the splanchnic at this level) gives rise to attacks of sneezing and to paroxysms of coughing and hiccough. Removal of the stellate ganglion causes in addition, first a mucous, then a purulent secretion from the nasal mucous membrane, and in one case it produced a chronic purulent bronchial secretion with lobular infiltration of the lungs. The attacks of cough and hiccough give the impression of nervous symptoms due to the loss of inhibitory action.

It is of interest to compare the occurrence of hiccough in these animals with Graham's conclusions. Graham found that excitation of the central stump of the splanchnic nerve (after severance of the latter) produces complete relaxation of the diaphragm and contraction of the abdominal muscles. Paralysis or destruction of the splanchnic nerve ought accordingly to cause the opposite symptoms, spasm of the diaphragm and relaxation of the abdominal muscles. This is the condition characterizing hiccough, and our findings—we mean the hiccough attacks observed—are in this respect in harmony with Graham's observations. A great difference however lies in the fact that in our experiments not only resection of a piece of the splanchnic nerve but also extirpation of the stellate ganglion gave rise to the hiccough attacks. A no less important difference was this, that in our animals the hiccough attacks did not make their appearance immediately, but weeks, and in the case of the splanchnic even four months after the injury inflicted.

The "coryza" and the "bronchitis" observed in two of the cases of extirpation of the stellate ganglion seemed more like trophic disturbances. The miliary tuberculosis observed in one case favors the theory of the nervous origin of tuberculosis, although one instance does not offer much proof of any theory.

We wish to emphasize that the respiratory disturbances were more grave in the case of removal of the stellate ganglion than in the case of resection of the thoracic sympathetic in its lower portion. To account for this we must not forget that the vagus nerve sends a powerful communicating branch to the stellate ganglion. This may also explain the presence of the "catarrhal" symptoms in case of removal of the stellate ganglion and their absence in the case of resection of the lower thoracic.

The cough and hiccough, however, could not be due to involvement of the pneumogastric alone, since they were observed also after resection of the lower part of the thoracic sympathetic, an operation which involved chiefly the splanchnic nerve.

One fact difficult of explanation is that in one of the three animals deprived of the stellate ganglion no symptoms were noted except sneezing attacks and these disappeared in the course of three weeks. That this absence of symptoms was due to the fact that in this case the right and not the left stellate ganglion was removed is very doubtful, although not absolutely impossible.

Chapter XI.

INVOLUNTARY AND AUTOMATIC MOVEMENTS.

Under this heading we wish to class the movements caused by non-striated muscles. The heart muscle has a structure which forms a transition between the striated and non-striated muscles. Owing to the intimate connection which the heart bears to the blood vessels we found it most convenient to discuss the sympathetic influence upon this organ directly after discussing the vascular functions.

It now remains to discuss the influence of the sympathetic system upon the movements of the stomach and intestines, the bladder, the uterus, the pupil, and on the erectors of the hair follicles (pilomotor nerves, Langley.)

I.—*The Movements of the Stomach and Intestines.*— In this paragraph we may at the same time discuss the vascular influence upon the stomach and intestines. The nerves presiding over the secretions of these parts we have spoken of in a preceding chapter.

The movements of the stomach and smaller intestines are under the control chiefly of the pneumogastric and the splanchnic nerves. As the investigations of Pflüger, of Meyer and Basch, and of van Braam-Houckgeest have shown, the actions of these nerves are to a large extent functionally antagonistic. The pneumogastric is chiefly a vaso-dilator nerve and excites the movements of the intestine and the stomach; the splanchnic inhibits them and it is at the same time vaso-constrictor. Morat has demonstrated however that this antagonism is not absolute. He was also able to demonstrate the inhibitory activity of the pneumogastric and on the other hand, the excito-motor (augmenting) activity of the splanchnics.

One splanchnic nerve can evidently functionally replace the other. Section of one of the splanchnics has no visible effects; but when both are cut an intense dilatation of all the small, even the smallest arteries of the stomach and small intestine occurs immediately and the movements of these organs become *more lively* (van Braam-Houckgeest). This indicates that both the vaso-constrictor and the motor inhibitory action of the splanchnics are under the tonic innervation of the nerve centres (spinal) with which they are connected.

According to Contejean, the pneumogastric nerve in the frog innervates the longitudinal system of muscular fibres of the stomach and contains also inhibitory fibres which may counteract reflex action of the stomach; the sympathetic, on the other hand, presides chiefly over the circular system of muscles.

Ehrmann, on the other hand (quotation from Hermann), finds that the pneumogastric excites the circular muscular fibres of the stomach and intestine and inhibits the longitudinal fibres, while the splanchnic excites the longitudinal fibres and inhibits the circular fibres. This conclusion is contradicted by Langley.

According to Langley the splanchnic fibres are derived directly from the spinal cord; that is, they undergo no cell interruption in the ganglia of the sympathetic cords. But they have their termination in the semilunar ganglia, and from the cells of the latter new fibres arise which establish the connection with the muscles and blood vessels of the stomach and upper intestine.

The lower segments of the intestine (colon and rectum) receive likewise a double nerve supply, namely from the lumbar (second to sixth in the cat), and from the sacral (second to fourth) nerve roots (Langley and Anderson). The fibres derived from the lumbar roots (visceral lumbar nerves) join the sympathetic and leave it for the most part with the cœliac or hypogastric nerves. The fibres derived from the sacral roots (visceral sacral nerves) pass into the nervi erigentes.

The two nerve plexuses differ not only in origin but also in function (Langley and Anderson). In the first place the visceral lumbar nerves contain vaso-constrictor fibres for the descending colon, for the rectum, and for the mucous membrane of the internal sphincter. Excitation of these nerves causes therefore, the parts supplied by them to become pale. These nerves further contain inhibitory fibres for the muscles of the colon and rectum and for the mucous membrane of the internal sphincter. Finally, the visceral lumbar nerves have a relationship to the skin surrounding the anus: they supply motor fibres for the non-striated muscles and for the constrictors of the blood vessels of this region.

The visceral *sacral* nerves are to a great extent antagonists of the visceral *lumbar* nerves. Excitation of them produces hyperæmia of the intestinal mucous membrane and strong movements of the longitudinal and circular muscles of the colon and rectum. The non-striated muscles of the skin of the anus are inhibited by these fibres.

In regard to the movements of the rectum Fellner had come to the following conclusions which are, as we have seen, contradicted in part by Langley and Anderson: 1. The nervi erigentes cause contraction of the longitudinal fibres and relaxation of the circular fibres of the muscles, shortening and thickening of the rectum, increase of volume, and diminution of pressure. 2. The hypogastric nerves have the opposite effect: relaxation of the longitudinal, contraction of the circular muscular fibres, lengthening and narrowing of the rectum, lessening of volume, and increase of pressure.

II.—*The Movements of the Bladder.*—It is proven by the investigations of Budge, Sokownin, Gianuzzi, Nussbaum, Nawrocki and Skabitschewski, Langley and Anderson, and Sherrington, that the bladder receives a double supply of motor nerves, viz.: (*a*) From roots of lumbar nerves (lumbar supply), and (*b*) From sacral nerves (sacral supply).

The fibres derived from the *lumbar nerves* leave the spinal cord by the anterior roots of the (third) fourth and fifth (in the monkey from the second, third, and fourth) lumbar nerves, and join the abdominal sympathetic nerve by the rami communicantes. From the abdominal sympathetic part of the fibres pass directly to the hypogastric and vesical plexuses (Nussbaum), the greater part, however, reach the inferior mesenteric ganglion by way of the mesenteric (superior, median, inferior) nerves and pass then into the hypogastric nerves which latter connect the inferior mesenteric ganglion with the hypogastric plexus.

The fibres derived from the *sacral nerves* leave the spinal cord with the anterior roots of the second, third (sometimes also the fourth and very seldom the fifth) sacral and pass from these nerves *directly to the hypogastric plexus*, without mediation of the main trunk of the sympathetic.

According to Langley, part of the motor fibres of the bladder are interrupted by cells of the inferior mesenteric ganglion, others probably by the cells of the hypogastric or vesical plexuses.

As the descent of the fibres to the bladder occurs in two different pathways, so their origin in the cord is probably twofold. That is, we must assume for many mammals the presence of two separate spinal centres of the bladder, one being situated in the lumbar, the other in the sacral portion of the cord. The position of these centres, although not exactly known, is indicated more or less by the level of the roots through which the motor fibres for the bladder leave the cord. Gianuzzi claims that in the dog they are situated at the level of the third and fifth lumbar vertebræ respectively. Sarbó reports a case of a man in which there had been incontinence of fæces and of urine in which the autopsy revealed a gliosis that had effaced the structure of the spinal cord almost entirely at the levels of the third and fourth sacral segments.*

*In looking over the proofs we find that the relation of the sympathetic to the functions of erection and ejaculation has been omitted. Regarding those functions one or two remarks must be added:

The vaso-dilator fibres, stimulation of which causes erection are contained in the nervi erigentes (Eckhard,—quoted from Hermann) which are formed by filaments passing from the sacral nerves (chiefly the 2nd and 3rd) to the hypogastric plexus, but some of these vaso-dilator fibres come from the lumbar sympathetic (dog) passing from there to the hypogastric plexus (Francois Frank—quoted from Hermann).

Concerning the pathways of the nerves presiding over ejaculation we find no definite notes in the physiological text-books.

The centres of erection and ejaculation (dog) are situated in the lumbar portion of the spinal cord (Goltz).

As has been mentioned in another paragraph, the bladder can act independently of the spinal centres, at least in the higher mammalians, (cat, monkey). After all the motor fibres leading to the bladder have been severed from the spinal cord, this organ still continues its functions for weeks (Zeissl). Its rhythmic action is the result of the nerve apparatus (hypogastric and vesical plexuses) placed within or on its wall (Zeissl, Sherrington).

III.—*The Movements of the Uterus.*—According to Langley all motor fibres to this organ are supplied exclusively from lumbar nerves and their further course is within the main trunk of the sympathetic from which they pass through the inferior mesenteric ganglion to the pelvic plexuses. Some authors, however, (Frankenhaüser, Kehrer, and others) claim a sacral supply in addition to the lumbar, stating that part of the motor fibres of the uterus pass directly from sacral (third, fourth,) nerves to the pelvic plexuses. According to Basch and Hoffmann (quotation from Hermann) the lumbar nerves act as motor nerves only of the longitudinal fibres, the sacral only of the circular fibres of the uterus. These statements are contradicted by Langley.

A great part of the motor fibres to the uterus are interrupted by cells of the inferior mesenteric ganglion (Langley.)

For parturition the centre situated in the lumbar portion of the spinal cord is sufficient, as this act has been observed in bitches with isolated lumbar portion of the spinal cord (Goltz, and others). As to whether parturition can take place if the connections with this spinal centre are severed, we can find no data.

IV.—*The Erector Muscles of the Hair Follicles and the Pilomotor Nerves.*—The name of pilomotor nerves is given by Langley and Sherrington to those nerve fibres that innervate the erector muscles of the hairs. According to these authors the pilomotor fibres pass through the anterior roots into the sympathetic nerve from which they take their course to the periphery. Experiments with nicotine prove that the fibres become interrupted* by cells of the sympathetic ganglia of the two gangliated cords. The pathway that the impulse takes from the spinal cord to the periphery consists thus, of two sets of neurons, one of which originates from cells of the spinal cord, the other from cells of the ganglia of the main trunk of the sympathetic.

The outflow of the pilomotor nerves from the spinal cord occurs through the rami communicantes of the fourth dorsal (seldom the third) down to the third or fourth lumbar nerves. (In cats and monkeys it is somewhat otherwise).

Excitation of the individual ganglia of the sympathetic nerve causes erection of hairs in definite circumscribed regions. Usually, but not always, the sympathetic (peripheral) fibres arise from cells of the nearest sympathetic ganglia, sometimes from the second nearest.

The pilomotor fibres and the sensory fibres can be traced

* Langley believes that there are justifiable grounds for the conclusion, that by stimulating the nerve fibres running to and from any peripheral ganglion before and after applying dilute nicotine to it, the class of nerve fibres which end around nerve cells of the ganglion can be distinguished from those which run through the ganglion without being connected with its cells. Nicotine seems to paralyze the conductive action either of the nerve cells of the ganglion or of the nerve endings in the ganglion; that is it seems to prevent the transmission of a stimulation from one neuron to another while it does not affect the conductivity of the nerve fibres. Therefore, if the ganglion is smeared with nicotine, direct stimulation of the nerve fibres passing out *from* the ganglion to the periphery retains in every case its full effect; but if after the application of the nicotine stimulation is applied centrad of the ganglion, *id est* to the nerve fibres passing *into* the latter (instead of *from* it) this stimulation will remain effective if the said fibres pass uninterruptedly through the ganglion, while it will have *no* effect if the stimulated fibres terminate around cells of the ganglion.

running together up to their entrance into the skin. There is no difficulty in showing that the greater part of the area supplied with pilomotor nerves by a given gray ramus is also supplied by sensory fibres of the corresponding spinal nerve (Langley).

While Langley and Sherrington allot to the various communicant rami definite circumscribed, although partly overlapping areas of distribution of pilomotor fibres, the result of our experiments appears to contradict such statement.

Langley and Sherrington state that in a monkey with severed cervical ganglion on one side fright caused erection of the hair only on the opposite side of the head. We have made the same test on two cats, in one of which the right stellate ganglion had been removed, while in the other a piece of the thoracic sympathetic of the right side comprising the eighth, ninth, tenth and eleventh thoracic ganglia had been resected. About three months after the respective operations the animals were brought into the presence of a dog, which had the customary effect of causing erection of all hairs on the back and head. In both instances this erection was equal on both sides, and equal in all areas of the same side. In the animal with the resection of the lower thoracic ganglia we observed that when the cat was stroked on the back and on the side of the chest and abdomen, but chiefly when stroked on the back, the hair stood up in an irregular stripe-like manner; so that longitudinal furrows alternated with longitudinal elevations. We must add, however, that this phenomenon is also met with in normal cats.

We must conclude, accordingly, *that although the pilomotor nerves have*, *on the whole*, *the segmental distribution which Langley and Sherrington attribute to them*, *there* *must be a collateral supply or a direct cerebro-spinal supply which in the case of removal of three or four successive ganglia can in the course of time entirely replace the functional loss thus created.*

V.—*Influence upon the pupil, eyeball, and eyelids.*—In 1727 Pourfour du Petit first demonstrated that section of the cervical sympathetic nerve is followed by contraction of the pupil and sinking in of the eyeball of the corresponding side. The contraction of the pupil was interpreted as being due to paralysis of the dilatator pupillæ muscle. The sinking in of the eyeball was explained partly by vasomotor effect, partly by the paralysis of Müller's muscle (Heese).

G. Fischer (quotation from Moebius) excited the cervical sympathetic nerve in the heads of two decapitated men. Faradic excitation produced opening of the palpebral fissure, dilatation of the pupil, protrusion of the cornea, and considerable lachrymal secretion.

Budge and others showed that the pupil dilating fibres of the cervical sympathetic are derived from the anterior roots of spinal nerves which joining the sympathetic nerve of the thorax by means of rami communicantes, pass through the ansa Vieussenii to the stellate ganglion from whence they take their course within the cervical sympathetic to the pupil. Budge and Salkowski found that the outflow of these pupil dilating fibres from the spinal cord takes place through the anterior roots and rami communicantes of the seventh and eighth cervical and the first and second dorsal nerves. Nawrocki noted their presence only in the eighth cervical and first dorsal, sometimes in the second dorsal anterior roots of the cat. Sherrington, who investigated the subject in monkeys, and Langley, whose observations were made upon cats and dogs, found them only in the first and second, to less extent, in the third, and very few if any in the fourth dorsal. Müller observed a man in whom a lesion could be distinctly located in the region of the first and second dorsal nerve roots, and in this case there was marked contraction of the pupil, ptosis and sinking in of the eyeball.

Comparing the results of these investigators, we find that the pupil dilating fibres occur with the greatest constancy in the first dorsal and almost as constantly in the second dorsal, to less extent and less constantly in the eighth cervical and third dorsal, and least constantly, it would seem, in the seventh cervical and fourth dorsal. This distribution varies not only with the species of the animal but also individually in the same species.

Budge placed the origin of the pupil dilating fibres of the cervical sympathetic in the so-called cilio-spinal centre which he found to occupy the region between the exits of the sixth cervical and third dorsal nerves in the spinal cord. Dastre and Morat confirmed Budge's conclusions. Salkowski and Knoll denied the existence of a cilio-spinal centre, and placed the origin of the pupil dilating fibres higher, Salkowski in the oblongata, Knoll in the anterior corpora bigemina.

On the other hand, clinical experience tended to confirm the existence of a cilio-spinal centre since oculo-pupillary symptoms were found to accompany transverse lesions of the spinal cord in the lower regions of the cervical and the upper regions of the dorsal portion of the cord (Kraus). This evidence was not conclusive, however, since in a case of transverse lesion of the spinal cord the fibres would also be severed in their course through the white substance, even if they originated from the oblongata or corpora quadrigemina. We might say that although the evidence is preponderatingly in favor of the existence of a cilio-spinal centre, yet the question has not been definitely settled.

Coleman Balogh and Francois Frank showed, however, that not all pupil dilating fibres contained in the first branch of the trigeminal nerve are derived from the cervical sympathetic, but that part of them reach the Gasserian ganglion by way of the roots of the trigeminal nerve.

Concerning the further course of the pupil dilating fibres of the cervical sympathetic only so much is known, that they all finally join the Gasserian ganglion and leave the latter with the first branch of the trigeminal nerve (Coleman Balogh, quoted by Jegorow and Dogiel). They then pass through the long ciliary nerves to the pupil without forming connections with the ciliary ganglion (Jegorow and Dogiel, Nawrocki and Przybylski).

That indeed not all pupil dilating fibres are contained within the cervical sympathetic nerve is amply confirmed by the results of some of our experiments. When the stellate ganglion of one side was extirpated together with the cervical sympathetic in cats, the immediate result was a narrowing of the pupil of the same side to about one-third of the width of the other pupil. Yet the pupil of the operated side continued to respond to light and to darkness. In the course of time the difference in the size of the two pupils became less and less marked so that after about three months it was hardly noticeable.

In one of the two cats which were allowed to live for three months after removal of the stellate ganglion on one side, we extirpated the stellate ganglion of the other side shortly before killing the animal, so that the latter was deprived of both cervical sympathetic nerves; yet both pupils still responded, which *proves beyond all doubt that not all pupil dilating fibres are contained within the cervical sympathetic nerve.*

The question whether the cervical sympathetic contains also pupil contracting fibres has, to our knowledge, been considered only by one author, viz., by Dogiel. He observed that when the sympathetic nerve of the neck was severed, faradization of the central stump causes dilatation of the pupil of the same side and simultaneously contraction of the pupil of the opposite side. The experiments were performed on cats and the size of the pupil measured by means of photographs taken before and during the experiments. The author concludes that there is a physiological connection of the sympathetic nerve with the pupil dilating centre of one and the pupil contracting centre of the other side (he finds that the pupil contracting and pupil dilating centres are connected in the same manner with the pneumogastric, sciatic, and auditory nerves).

Dogiel found further that excitation of the peripheral (head) end of the sympathetic nerve of the neck causes dilatation on the eye of the same side, contraction of the pupil of the other side.

Our experience is in accord with that of Dogiel. From our experiments we are able to say that the sympathetic nerve contains not only dilator but also contracting fibres for the pupil. *We found, however, that it contains contracting fibres for the pupil of the same side.* As mentioned already, we removed in the same cat first the left, and three months afterwards the right stellate ganglion. After the second operation, when the animal had recovered from the effects of the ether narcosis, tests showed that the left pupil contracted much more promptly and much more narrowly when light was thrown on it than the right one. This can be explained in the following manner: The cervical sympathetic nerves contain not only pupil dilating but also pupil contracting fibres for the same side. The loss of these fibres that takes place after the severance of the stellate ganglion from the cervical sympathetic is almost entirely compensated for in the course of three months. Therefore, if one stellate ganglion was removed three months previously to the test, the other directly before the test, the pupil of the side first operated upon contracted much more intensely and promptly than that of the other side.

We are aware of one valid objection to our argument, namely, that the test was applied directly after the extirpation of the stellate ganglion, when, owing to this injury, the nerve fibres (and nerve cells?) concerned could be still under the influence of shock which might account for their sluggish and lessened activity. The reason why we did not attempt to verify our results by repeating the test the following day or still later, was that we did not want to complicate our histological research by creating *bilateral* ascending changes in the cerebro-spinal axis.

In addition to contraction of the pupil, section of the cervical sympathetic nerve causes a sinking in of the eyeball into the orbit, slight ptosis of the upper lid, and paralysis of the nictitating membrane. Heese finds that excitation of the sympathetic nerve causes protrusion of the eyeball in cats and dogs, while in rabbits it produces intense sinking in of the eyeball. This discrepancy he explains by the fact that the sympathetic nerve displays its effect upon the eyeball in two ways. First by the contraction of Müller's muscle, second by vasomotor influence. The former causes protrusion, the latter a sinking in of the eyeball. In cats the effect upon Müller's muscle predominates, therefore the protrusion; in rabbits the reverse is true.

According to Langley, the nerve fibres causing retraction of the nictitating membrane (third lid) and opening of the eyelid have in the cat a more extended origin than the dilator fibres for the pupil. They arise from the first four thoracic nerves, and sometimes from the fifth also. In nearly every case the second thoracic is most effective, the first more than the third; the fourth has slight effect, the fifth at best causes but a trifling movement.

That the cervical sympathetic has an influence upon the shape of the cornea is claimed by Claude Bernard, Brown-Séquard and Hermann, who find that section of the cervical sympathetic causes flattening of the cornea. Their statements have been contradicted by Heese. Heese declares that the conclusions of Morat and Doyon, who contend that the sympathetic nerve influences the shape of the lens by displaying an effect antagonistic to that of the third nerve upon accommodation, are likewise erroneous.

The trophic disturbances observed in the eye after removal of the stellate ganglion will be discussed in the next chapter.

Chapter XII.

TROPHIC AND TONIC FUNCTIONS.

I.—*Trophic Functions.*—The trophic action of the sympathetic nerve was first demonstrated by Heidenhain on the parotid gland.* He showed that when this gland has secreted from two to three cubic centimetres of saliva

* See foot-note, page 63.

under the influence of the sympathetic nerve, the character of its cells is changed to such a degree that one thinks he has to deal with a completely new organ. Langley made similar observations but found that the trophic fibres in the dog were contained in the cerebral secretory nerve (chorda tympani).

Afanassiew found that section of the nerves of the liver was followed by swelling of the liver cells which caused an appearance similar to that observed after fibrin feeding.

Howell states, regarding the pancreas, that in accepting the theory of trophic and secretory fibres, experiments seem to indicate that in the sympathetic, trophic fibres (for the pancreas) are more abundant, and that in the pneumogastric the secretory fibres predominate.

Retraction of one side of the face and loss of hair have been observed after lesions of the cervical sympathetic in man (Jacobsohn). Moebius contends that the true form of facial hemiatrophy, characterized by discoloration and wasting of the skin, discoloration and disappearance of the hairs, wasting of the bones and cartilages, differs entirely from the slight flattening of the cheek observed with disease of the cervical sympathetic nerve. On the other hand, Angelucci has seen very marked trophic disturbances follow extirpation of the stellate ganglion and we can confirm in part his results from our own observations. He found that in new-born dogs and in adult cats defect of one stellate ganglion gave rise (on the side of the operation) to alopecia of the face, dystrophy of the cranial bones and deficient development of the teeth. In adult rabbits and monkeys these conditions were not usually met with.

Our own experiments on young cats have given similar *results.* A few days after removal of one stellate ganglion, or of some of the lower thoracic ganglia, red, hairless spots were seen on the head of the animals. At first slight heed was given to these as it was thought that the animals, who played much around the stove had burned themselves. Observations on other operated cats showed, however, that these spots were not accidental but a consequence of the injury to the sympathetic nerve or ganglia. After some time the spots became scaly, psoriasis-like, gradually turning into pale, smooth patches which, however, grew red on the least irritation. In the course of about a month they healed up entirely and became covered with a new growth of hair. The size of the diseased areas varied from the size of a cent piece or less to the size of a 25 cent piece or even larger.

When these spots occurred after the removal of one stellate ganglion their localization was confined to the head, but on both sides. In the two cats which had suffered removal of the lower thoracic ganglia, the *head* showed most of the patches, on both sides; but the diseased areas were also met with in other localities, for instance, over the middle of the dorsal spine, (median line), over the sacral region, (also median line), on the right fore paw, above the foot joint, etc. The distribution seemed to be quite irregular and arbitrary in these cases.*

*Max Joseph (Virchow's Archives, Vol. 107, p. 119) operated on the second cervical nerve in young cats, and extirpated a continuous portion including a piece of both roots, the entire spinal ganglion, and a piece of the peripheral nerve. This operation evidently implies tearing off the ramus communicans of the nerve and it is interesting to note that he also observed hairless spots on the face of the animals such as we found. Of no less interest is the fact that when he cut both roots of the second cervical nerve without injuring the spinal ganglion or any part of the nerve trunk peripheral to the ganglion, the hairless spots did not appear. From this the inference seems justified that the trophic influence of the sympathetic efferent fibres of the ramus communicans is sufficient to prevent the loss of hair, since in the latter experiment the cerebro-spinal motor fibres of the ramus communicans were cut in their course through the anterior and (posterior?) roots, while the sympathetic efferent fibres were left untouched. Text-Figure No. 4 makes these conditions clear.

Gaule has noted that lesion of the stellate ganglion in rabbits gives rise to almost instantaneous changes in the biceps femoris and psoas muscles. These consist of vascular suffusion of the surrounding connective tissue and an ulceration of the muscles that causes them to separate into two parts. This condition was reached only when the ganglion was partly, not when it was totally extirpated. Salvioli and Hering contend that the muscular changes observed by Gaule were due entirely to excessive stretching of the muscles caused by the tieing of the animal on a board, and that if such stretching is avoided irritation of the stellate ganglion causes no muscular lesions. This seems to us a not improbable explanation.

Angelucci has seen, in addition to the trophic changes referred to, interesting alterations in the eye follow extirpation of the stellate ganglion in new-born dogs, such as lesser development of the circumference of the cornea and sclera, the eyeball showing a lessening of about one millimetre in its diameters. Both in new-born dogs and in adult cats, a long time after the extirpation of the stellate ganglion, distinct dystrophies characterized by simple atrophy and sclerosis occur, especially of the texture of the iris and of the choroidea. In the iris of new-born dogs the sclerosis of the tissue formed large plaques. The fundamental structure of the retina, however, was never found altered. Angelucci attributes the dystrophies reported to changes in the blood vessel walls, to which Vulpian and Giovanni had already called attention.

From all the facts mentioned, the important relation which the sympathetic nervous system bears to the trophic functions of the organism becomes highly evident.

II.—*Tonic Functions.*—It has been shown that many nerves of the sympathetic system are under the tonic influence of spinal or cerebral centres. Section of the cervical sympathetic nerve is followed by dilatation of the blood vessels of the head; section of the abdominal sympathetic by dilatation of the blood vessels of the hind paws; section of both splanchnics by the same phenomenon in the stomach and the intestine. Severance of the nerves connecting the submaxillary ganglion with its encephalic centre gave rise to an unceasing continuous secretion of the submaxillary glands, proving the regulatory influence of the cerebro-spinal system upon the submaxillary ganglion (Claude Bernard). We recall further the experiments of Spallita and Consiglio, which showed that the tonus of the whole vascular system is kept up and regulated by means of the vaso-sensitive nerves.

Regarding the tonic influence of ganglia of the sympathetic itself, the views still differ. Tuwim claimed tonic effects of the stellate ganglion upon the pupil dilating fibres but such effects were denied by Schipiloff. We know, however, that the heart removed from the body still continues to beat, and that the bladder deprived of the motor nerves leading to it continues to perform its functions. It is quite questionable if the functions of maintaining tonus are different materially from the functions discussed under the heading of Vascular Functions (p. 72).

Chapter XIII.

REFLEX ACTION OF THE SYMPATHETIC SYSTEM.

We have already mentioned some facts that point to a considerable functional independence of the sympathetic system apart from the spinal and cerebral centres. We remind the reader of the two facts regarding the independence of the bladder and of the heart functions mentioned at the end of the preceding section and of the observations of Contejean, according to which the secretion of gastric juice continues after the stomach has been deprived of all its nerve connections.

This independence of the sympathetic system from the cerebro-spinal system is further demonstrated by the reflex action of sympathetic ganglia, which must now be regarded as an established fact. Sokownin, Nussbaum, Nawrocki and Skabitschewski, and Langley and Anderson, proved such reflex action for the inferior mesenteric ganglion. Nawrocki and Skabitschewski severed all nerve filaments passing to the inferior mesenteric ganglion with the exception of the hypogastric nerves. Then when one of the hypogastric nerves was cut through and the central stump of this nerve stimulated (by mechanical irritation so as to exclude the error which might occur with electrical excitation) contraction of the bladder followed, no matter whether the severed nerve was the right or the left hypogastric.

Claude Bernard established the fact of the reflex action for the submaxillary ganglion. Francois Frank showed it for the ophthalmic (ciliary) and for the superior thoracic ganglion. Regarding the latter, he found that centripetal excitation of the ansa Vieussenii transforms itself in the first thoracic ganglion isolated from the centres, into a motor excitation transmitted through the posterior branch of the ansa Vieussenii. In other words, this excitation produces, independently of the bulbo-medullary centres, a reflectory augmentation of the action of the heart, reflectory constriction of the blood vessels of the middle ear, of the submaxillary gland, and of the mucous membrane of the nose.

Chapter XIV.

THE FUNCTIONAL INTERRELATION OF THE SYMPATHETIC AND CEREBRO-SPINAL SYSTEMS.

After having shown the degree to which the sympathetic nervous system may functionate independently of cerebral and spinal centres a word must be said regarding the extent and manner of its dependence upon the cerebro-spinal system. In this connection we recall Claude Bernard's observation of the paralytic secretion which occurs in the submaxillary gland after all nerve connections of the submaxillary ganglion with the cerebro-spinal axis are severed, and which finally leads to functional destruction of the gland. The fact that certain fibres or nerves of the cerebro-spinal system exhibit a marked tonus upon certain vegetative functions is another evidence of the dependence of the vegetative functions upon the cerebro-spinal centres.

We have now to investigate the nature of the relationship existing between the sympathetic and the cerebro-spinal system. While the muscles of the somatic sphere can be made to act voluntarily, it is known that normally the vegetative functions can not be influenced by the will. But the vegetative nervous system can be stimulated to strong action by emotions. The diarrhœa produced by fright, the blush of shame are two familiar examples of such action.

What then is the essential difference between voluntary and emotional neural activity? It is agreed that voluntary motion emanates from the cerebral cortex, but there is no doubt that the cortex participates likewise in the enactment of emotional processes since we become conscious of our emotions. Moreover, although under normal circumstances visceral nerve stimuli do not rise to consciousness we become conscious of them either in case of increased visceral action (for instance we feel palpitation when, owing to exertion, the heart beats with increased vigor and frequency), or in case of sensory hyper-excitability of the visceral nerve apparatus from peripheral causes, or of sensory hyper-excitability of central origin such as in hypochondriasis and neurasthenia.

Consequently, if it is possible to become conscious of visceral sensory stimuli, this proves that such stimuli are conducted to the cortex and, if such is the case, we are justified in maintaining the existence also of a motor or efferent vegetative pathway from the cerebral cortex to the vegetative organs. Indeed Bechterew and Mislawski by exciting a certain region of the cerebral cortex in dogs have been able to produce lachrymal secretion, an exquisitely vegetative function. It is remarkable to note further that under abnormal circumstances the will can influence vegetative functions. As an example of this we quote an observation of Bechterew concerning a hysterical patient who by force of will could change the size of her pupils. The fact that voluntary visceral nerve action may occur under abnormal circumstances proves the existence of a motor pathway from the cerebral cortex to the vegetative organs. Why then under normal circumstances can not the vegetative functions be acted upon by the will while they can be by emotion? The most plausible explanation, at least for the vegetative functions, is that the emotions are much more powerful stimuli than the will and that under common conditions the latter does not give stimulation enough to produce noticeable centrifugal (visceromotor, vasomotor, etc.) action. The reasons for this difference between the enactment of somatic movement on one hand and that of visceral or other vegetative functions (vascular, secretory) on the other are probably manifold, but one of them must evidently be sought in the peripheral organs performing such function. It may be that the striated muscular fibre is in general more susceptible to stimulation than the non-striated fibre or the cell of the secretory gland; or that there is a greater susceptibility of the striated muscle to excitation by the nerve current; or, finally, that the manner of connection of the nerve fibre with the contracting or secretory organ respectively is better fitted for the transmission of the nerve impulse in the case of striated muscular fibre.

Another reason why contraction of striated muscles can be called forth not only by emotions but also by the will while the latter is unable to influence the vegetative functions, may be sought for in the fact that on the whole, a more linked chain of neurons would have to be traversed for the "cortical" enactment of vegetative function than for the enactment of voluntary contraction of striated muscles. According to Langley and Kölliker an efferent stimulus starting from the cerebral cortex will have to pass (as a rule or always ?) three neurons in order to reach a vegetative organ, and Jendrassik postulates the existence of efferent pathways of even four neurons. On the other hand, we know that the striated muscles can be influenced from the cerebral cortex through a pathway consisting of two sets of neurons, the cortico-spinal (or cortico-bulbar, etc.) and the spino-muscular (or bulbo-muscular, etc.). But whether or not this more linked arrangement in case of the vegetative system is the main cause of the impossibility of voluntary function remains debatable.

Another factor seems no less important. What we call voluntary movement is voluntary only to a certain degree. We are not able to voluntarily contract individual muscular fibres or muscular bundles but only such groups of muscle bundles or muscles whose simultaneous contraction produces a definite effect. What is voluntary is accordingly not the contraction but the total effect. If the anatomical condition of parts is such that they allow only forward and backward motion in one and the same direction, it is natural to assume that in this case the same muscles will always act. We believe it probable for instance, that in order to flex the ulna on the humerus from an angle of 180° to one of 170° the muscles concerned in effecting this motion would always be the same. But if we come to the practical point of bending the whole forearm on the arm it would be different because in this case the muscular action necessary to produce the flexion would vary with every position of the radius. In this act, again, only the reaching of the effect would be voluntary. To reach the effect, however, we are chiefly guided by sensation, be it visual, tactile, muscular, joint sensation, or all of these, and of these sensations we are highly conscious in learning any new voluntary act. By a constant variation of conditions and a frequent repetition of the same condition the kinæsthetic sensations reach a high degree of certainty and accuracy; and the greater the accuracy attending sensation, the more accurate, certain, and more voluntary our motions become. On the other hand, how is it with our visceral sensations? It is certain that in the viscera we can not adapt outer conditions so as to obtain practice and routine for the visceral sensations. We can well understand, therefore, that these sensations remain vague and do not as a rule reach consciousness. It is this very vagueness of the visceral sensations that takes away the means of conscious guidance of visceral motion and of other vegetative functions, and this in a measure explains why we are not able directly to influence the vegetative functions by the will.

We shall close this argument by calling attention to Polakoff's interesting experiments* which have a direct bearing upon this subject. Polakoff found that anæsthesia of the upper lip of the horse, produced by section of both infra-orbital nerves, is accompanied by a paralytic state of the upper lip (pseudo-paralysis), so that voluntary prehensile movements of the upper lip in feeding are impossible; to compensate this the animal uses its lower lip, tongue and teeth with increased energy. This paralysis is not complete, as occasionally voluntary movements of the upper lips for the purpose of seizing food are noticed, but these movements are rare, weak and inco-ordinate. The author states that lesion of motor pathways was absolutely excluded in his experiments and that the paralytic condition was due entirely to the anæsthesia.

Chapter XV.

GENERAL REMARKS ON METHODS OF PHYSIOLOGICAL RESEARCH ON THE SYMPATHETIC.

The essential influence which the sympathetic system exercises on the vegetative life of the organism has been amply demonstrated in the foregoing review. Inasmuch as some vegetative functions are exquisitely vital, we may

* *Journal of Nervous and Mental Disease*, 1895, p. 375.

say also that the sympathetic system possesses in high degree vital functions. This is confirmed by our observations. In very young cats lesions of the important parts of the sympathetic invariably proved fatal. Even if the animals outlived such operations as extirpation of the semilunar ganglion or removal of the stellate ganglion or resection of the lower part of the thoracic sympathetic, they invariably died, and usually a few hours or days after the operation. One cat four weeks old survived the removal of one semilunar ganglion three weeks, being at first quite playful and apparently healthy, but at the end of two weeks he was attacked by diarrhœa and died in a state of collapse. Even a cat of five and a half weeks in which we had removed three lumbar ganglia would have died from collapse two weeks after the operation had we not preferred to kill it by chloroform, and in this case no attributable cause of the collapse except the defect of these three ganglia could be found. There had been neither suppuration nor peritonitis.

We desire to call attention to the fact that the death of many animals during the operations was caused by pulling upon the sympathetic nerve or bruising of a sympathetic ganglion. We noted that this was especially the case in operating to remove the stellate ganglion. Although the animal would be breathing vigorously and freely immediately before, as soon as the stellate ganglion was pulled upon or as soon as its connection with the thoracic sympathetic nerve was severed respiration suddenly became arrested and the animal promptly died.

With older animals, that is with cats which had reached the age of five or six weeks, we succeeded much better and three of them lived from three to five months after the operation, when they were killed.

In closing this chapter, we wish to call attention to a method of physiological research which may serve to enlighten us on points for which the other methods give insufficient information. This method consists in studying not the immediate but the remote effects of injuries of certain loci of the nervous system; of investigating not only the perversion or loss of function which is the immediate result of removal or section of some ganglion or nerve, but also the compensation of the functional defect that occurs in the course of time. In this manner it is often possible to determine whether certain functions are performed exclusively by a definite nerve or ganglion or whether other nerves or ganglia share in the fulfilment of this function. Illustrations of the truth of this are given in the observations made by us on the pupil of cats in which a stellate ganglion had been removed. The immediate consequence of this operation was reduction of the size of the pupil of the operated side to one-third or less the size of the other pupil. Gradually, however, the difference in the size of the two pupils diminished until in the course of from three to five months the difference had entirely disappeared, showing in the most convincing way by this compensation of function, that not all pupil dilating fibres are derived from the cervical sympathetic nerve and stellate ganglion. The method mentioned has given another interesting result bearing on the same point. When three months after the removal of one stellate ganglion, the ganglion of the other side was removed, a test of the pupillary reaction showed that the pupil of the side first operated upon contracted much more intensely and more rapidly to light than the other pupil. This fact can hardly be explained otherwise than by granting that the cervical sympathetic contains not only pupil dilating but also pupil contracting fibres. The defect of function caused by removal of these fibres becomes compensated for in the course of time. Owing to this compensation the pupil of the side on which the stellate ganglion had been removed three months previously to the test, contracted much more promptly than the pupil of the other side, on which the ganglion had been extirpated just before the test.*

No less interesting were the results which we obtained regarding the sweat fibres of the fore paw of the cat and regarding the influence of the cervical sympathetic on lachrymal secretion. Twenty-five days after extirpation of the left stellate ganglion, injection of one centigramme of pilocarpine caused no perceptible change in the state of the left fore paw, while when an injection or instillation of pilocarpine was made three or four and a half months after this operation (in two other cats), the fore paw of the operated side sweated quite abundantly and in one case apparently no less than that of the other side. (Regarding the effect of physiological stimulation on the sweat secretion in one of these cases see page 61). Moreover injection of pilocarpine three weeks after extirpation of the left stellate ganglion caused profound lachrymal secretion on the healthy side, the eye of the operated side remaining dry, while on the contrary three months after this operation, (in another cat) the eye of the operated side secreted much more than that of the healthy side when pilocarpine was injected. Finally, in a third animal four and a half months after extirpation of the ganglion, pilocarpine instillation produced lachrymal secretion of both eyes in an equal degree.

* The influence of shock can not be entirely excluded, since the test was made immediately after the operation, as soon as the animal came out of the ether narcosis.

The contrast between the direct and the remote consequences of the defect of certain parts of the sympathetic system is further shown in quite an opposite direction. While such defects seem at first not to cause any disturbances of certain functions, such disturbances often make their appearance weeks and even months after the injury was produced, and show a tendency to progression. No legitimate conclusions could be drawn as to the effect of the removal of the stellate ganglion upon the gastric and intestinal functions during the first four weeks after such removal, because during this period these functions appeared quite normal. Nevertheless, they became profoundly disordered later. In the same manner two cats which were deprived of the semilunar ganglion showed no symptoms in the first two weeks after the operation but at the end of that time one of them was taken with vomiting and diarrhœa, and finally, three weeks after the operation it died in a state of collapse. The second cat did not begin to have vomiting attacks until three weeks after the injury had been inflicted.

In like manner the disturbances of respiration observed after removal of the stellate ganglion or the lower portion of the thoracic sympathetic nerve differed in their immediate and remote consequences. In one case for instance, pertussis like paroxysms set in as late as two months after resection of the thoracic sympathetic nerve with the adjoining piece of the splanchnic. The clinical significance of such facts as these is surely so important and obvious that this aspect needs no specific elaboration.

PART III.

THE LOCALIZATION OF THE SYMPATHETIC NERVOUS SYSTEM.

CHAPTER XVI.

THE STRUCTURAL INTERRELATION OF THE CEREBRO-SPINAL AND SYMPATHETIC SYSTEMS.

We have seen that connection is established between the spinal cord and the brain on one side and the sympathetic nervous system on the other either by means of the rami communicantes of spinal nerves or their homologues in the cranial division of the nervous system, or by the rami which pass from cerebro-spinal nerves to the great sympathetic plexuses. We must seek therefore—in the spinal cord and brain—for centres presiding over the motor, or better said, efferent functions of the sympathetic system, and for receptive centres whose function is to receive sensory impressions from the viscera, blood vessels and glands, and to convey them upwards, *i. e.*, toward the cerebellum and the cerebral hemispheres.

Some authors have speculated from clinical data alone, concerning the location of these centres. For instance according to Mott, Ross was the first to suggest that in tabes the visceral crises and other disturbances of a similar nature are due to affection of the cells of Clarke's columns. Sachs ("Nervous Diseases of Children," page 276) says: "It is not a great stretch of imagination to suppose that tactile sensation and the sensory impulses by which reflex action is excited, pass through the lateral series of fibres whereas those fibres connecting with the columns of Clarke in all probability have to do with the functions of co-ordination and with the transmission of visceral sensations." But the merit of the first attempt to study in a systematic manner the distribution of the "visceral" nerves in the brain and spinal cord is due decidedly to Gaskell. To enter into the details of the highly ingenious plan on which his researches were conducted would lead too far. We can only hint at some of the principal points: Gaskell had demonstrated that in the nerve roots of the cerebro-spinal nerves certain medullated fibres distinguish themselves by the fineness of their calibre. He had shown in a convincing manner that these fine fibres represented the visceral fibres of the roots. Furthermore, he had demonstrated the presence of these fine medullated fibres in many of the rami communicantes. Before Langley had made his interesting researches on the action of nicotine on the sympathetic ganglia and before the method of metal impregnation had become really known, Gaskell was able to prove in a very clear manner, as we have already pointed out on page 36, that the conversion of medullated into non-medullated fibres in a sympathetic ganglion was due to connection in some way with the nerve cells of the ganglia.

On the other hand he could trace other medullated visceral fibres passing through ganglia of the sympathetic chain without altering their character, and becoming non-medullated only after they had reached some of the peripheral sympathetic nerve plexuses. Evidence was adduced by him to show that among the vascular fibres for instance, those which were thus "converted" in the proximal ganglia of the sympathetic (that is, in the ganglia of the sympathetic chain and its homologues), were in all probability vasomotor, while those which were converted only after they had reached the peripheral plexuses were very probably vaso-inhibitory.

In a similar manner Gaskell made distinctions between vascular and visceral fibres proper; between viscero-motor and viscero-inhibitory fibres; etc. He showed further how the presence at certain levels of the cord of definite cell groups coincided with the occurrence in the corresponding anterior nerve roots of a certain class of fibres. We shall cite only the following statement bearing on this:

"Thus the cells of Clarke's column are found in the cranial, thoracic, and sacral splanchnic regions; consequently they do not give origin to the vaso-constrictor nerves,—*i. e.*, the katabolic nerves of the muscles of the blood vessels,—which arise only in the thoracic region and with vaso-constrictor nerves the katabolic glandular nerves are in all cases closely associated, so that these two categories of nerves may be eliminated from the consideration of Clarke's column. Further, Clarke's column is most developed from the 9th dorsal to the 3d lumbar nerve, and therefore it is associated with the abdominal splanchnics, rather than with the cervical splanchnics. We know, on the other hand, that the great function of these abdominal splanchnic nerves is to inhibit the movements of the alimentary tract. The natural conclusion is that the cells of Clarke's column are associated with anabolic (inhibitory) rather than with katabolic (viscero-motor, vasomotor) nerves and that they give origin to the inhibitory or anabolic nerves of the muscles of the alimentary canal and perhaps also to the corresponding nerves of the vascular and glandular systems. This conception is in harmony with their presence in the sacral region, in connection with the nervi erigentes, and in the upper part of the cervical region, where the inhibitory cardiac nerves are given off."

Reasoning in this manner Gaskell comes to the following conclusions regarding the functions of those nerve nuclei of the spinal cord and oblongata which give origin to the efferent (centrifugal) fibres of the nerve roots.

A. (Cells of the anterior horns) =Nucleus of efferent nerves to somatic muscles.	Represented in the medulla oblongata by the hypoglossal nucleus.
B. (Large cells of lateral horns) =Nucleus of efferent nerves to striated splanchnic muscles.	Represented in the medulla oblongata by the nucleus ambiguus (motor vagus nucleus).
C. (Cells of Clarke's columns)= Nucleus of anabolic (inhibitory) nerves to splanchnic glandular system and to muscles of viscera.	Represented in the medulla oblongata by the nuclei at the floor of the 4th ventricle known as the accessory and the dorsal vagus nuclei.
D. (Solitary cells of posterior horn)=Nucleus of motor nerves to muscles of viscera.	No mention made respecting their possible representation in the medulla oblongata.
E. (Small cells of lateral horn) =Nucleus of katabolic (motor) nerves to splanchnic glandular system and to muscles of vascular system.	

For the afferent (sensory) fibres Gaskell makes the distinction of *somatic* and *splanchnic* afferent fibres. In the oblongata the somatic afferent root is represented by the ascending (which according to most recent trustworthy investigations we shall have to call descending) 5th root, while the splanchnic afferent fibres are represented in the solitary bundle (respiratory bundle, ascending root of the lateral mixed system descending root of the IX and X).

There can be no doubt that some of the premises on which Gaskell bases his conclusions are, at least in part, erroneous. It is an erroneous statement for instance, that the vaso-constrictor nerves arise only in the thoracic region of the spinal cord. Yet we shall see that in the main Gaskell has hit very near to the mark in most of his final conclusions, and we can but praise his ingenious researches and recommend them for close study to him who wishes information of the structure and central distribution of the sympathetic nervous system.

Mott contends against Gaskell's views that the axis cylinder processes of the cells of Clarke's columns become fibres of the anterior roots, claiming justly that these axis cylinders are continued as fibres of the direct cerebellar tracts. We must not forget, however, that there are two sets of cells in Clarke's columns, large ones and small ones, and it is not altogether disproven that part of the cells of Clarke's columns may yet give origin to axis cylinders taking the course which Gaskell attributes to them. Indeed Mott, and likewise Bechterew, saw fibres passing from Clarke's columns forward to the anterior horns, and we have been able to confirm these observations. Mott finds further that peripherad Clarke's columns are connected with the posterior roots and he says that these latter conduct impressions connected with the preservation of equilibrium from the extremities and viscera to Clarke's columns whence they are conveyed to the cerebellum by way of the direct cerebellar tracts. This conception will probably withstand the test of time.

Mott considers the nuclei of the funiculi cuneati and Deiter's nucleus the homologue of Clarke's column in the oblongata. Blumenau had previously come to the conclusion that the large cells in the lateral portions of the funiculi gracilis and (chiefly) cuneatus are the homologues of Clarke's columns. Mott's further views regarding the connections of the sympathetic nervous system with the cerebro-spinal axis may be summed up as follows:

"The fine, centrifugal, splanchnic fibres which Gaskell found in the anterior roots originate from the bipolar cells of the tractus intermedio-lateralis (lateral horn) and from the solitary cells of the posterior horn. The vago-glosso-pharyngeal nucleus (the one situated beneath the floor of the 4th ventricle) is to be considered as the continuation of the tractus intermedio-lateralis, having the same physiological significance in the medulla oblongata as the latter has in the cord. Other larger cells of the tractus intermedio-lateralis have altogether other functions and are perhaps related to the antero-lateral tract."

We must demur to Mott's statement that the dorsal vago-glosso-pharyngeal nucleus is a continuation of the tractus intermedio-lateralis. This tract has an altogether different position and is quite distinctly represented in the processus reticularis of the upper cervical region at the level in which the vago-glosso-pharyngeal nucleus is already distinctly present.

Biedl cut the splanchnic nerves in dogs and studied the ascending degeneration in the spinal cord. His conclusions are formulated in rather a vague manner so that it is difficult to gather where he conceives the location of the centres of the efferent fibres to be and where he believes the afferent fibres end in the spinal cord. Yet it would seem that he found a splanchnic motor centre in the lateral horn of the lower cervical and upper dorsal regions. We must not forget to add that the purpose of Biedl's researches was not so much to establish the *localization* of the splanchnic nerves in the spinal cord as it was to study the *histological character* of the spinal cell changes after section of the nerve.

Aside from the investigations just discussed (Gaskell's, Mott's and Biedl's) we have found no literature relating to the localization of the sympathetic or visceral nerves in the spinal cord or brain.

We shall now proceed to the report of our own investigations.

Chapter XVII.

GENERAL PLAN OF THE EXPERIMENTS.

Our object in instituting this series of experiments was to determine, first, whether lesions of ganglionic masses situated somewhat peripherally would produce definite, recognizable changes in the spinal cord. If this were so, it would allow us to locate the spinal centres presiding over definite nerve plexuses, such as the cardiac, solar and hypogastric. With this inquiry in mind our first experiments consisted of extirpation of the left semilunar ganglion in young cats, which were sacrificed three and three and one-half weeks, respectively, after the operation.

As we had anticipated and feared, however, the results obtained were in every way unsatisfactory. Microscopical examination did not reveal any significant or important changes. Although some morbid processes might perhaps have been found if we had made exhaustive series of sections and subjected them to methodical and thorough examination, it was deemed more rational to change our plan of investigation and attack the sympathetic system in its most central part, that is, as near as possible to its origin from the spinal cord. We determined, therefore, to operate directly on one of the great gangliated cords, and to produce lesions at various levels, namely, in the cervical, thoracic, and lumbar portions. In this manner, it seemed that we might orient ourselves concerning the central connections of nearly all parts of the sympathetic nerves. In pursuit of this plan the following experiments were performed:

First.—*Extirpation of the stellate ganglion in three cats.*

SECOND.—*Resection of the lower part of the thoracic sympathetic nerve, inclusive of the corresponding thoracic ganglia and the adjoining piece of the splanchnic nerve. This injury was inflicted upon two young cats.*

THIRD.—*Resection of a segment of the lumbar portion of the gangliated cord on one side. This operation was made on one young cat.*

Our idea originally was to study the degeneration of the fibres that ensued, by means of Marchi's method alone. Experience in one case (extirpation of three lumbar sympathetic ganglia) had shown that this method was very satisfactory for following the course of the sensory fibres concerned, but it had demonstrated also that the alterations produced in the motor fibres were so slightly marked that definite conclusions could not be drawn. We determined, consequently, for the ensuing operations to follow Gudden's method as far as possible. We say as far as possible, as our attempts to operate on new-born animals failed. They did not survive the injuries inflicted. Eventually, then, the plan adopted in several cases was to operate on cats which had reached the age of from five weeks to two months, and to allow the animals to live for a period of from three to five months.

The staining methods employed (aside from Marchi's) were chiefly those of Nissl and of Pal. In those instances in which carmine was used, we stained the specimens *en bloc*, before preparing them for paraffine embedding. In order that both the fibres and the cells might be studied in a given case, either we divided one segment of the spinal cord into two parts, one of which underwent handling preparatory to Nissl's stain (hardening in alcohol) while the other part of the segment was hardened in Müller's fluid to make it available for Pal's stain; or we used alternately Nissl's stain for one segment, Pal's (or Marchi's) for the next, etc.

The various segments of the spinal cord were studied by means of long, unbroken series of cross-sections, or when cross-sections did not seem to give clear information, continuous and successive series of longitudinal sections were made.

In three animals the stellate ganglion had been extirpated, but in one of them the central nervous system was not examined. In the other two both the spinal cord and the oblongata were studied. One oblongata was hardened in Müller's fluid, and an almost unbroken series of cross-sections was made, which were stained partly with carmine and partly with Pal's method. The other oblongata was prepared for Nissl's method, and a continuous series of cross-sections was made. Of this series we preserved and stained every second, fourth or fifth section. For comparison the oblongata of a normal cat was cut *seriatim* and every fifth section preserved and stained. All specimens preparatory to cutting went through the process of paraffine drenching and embedding. Altogether, our investigations comprised the study of between 3,000 and 4,000 sections.

The anatomical material of our investigations was ranged in among the other material of the Pathological Institute of the New York State Hospitals from which this monograph is issued. In arranging our cases we followed the system* used in the Pathological Institute. The several animals experimented upon were thus recorded under the case numbers 410, 411, 412, 413, 414,

*In this system by means of the card catalogue and a decimal notation with accession numbers for each case, the data of the entire technique from the preservation of the material to the examination of the sections on the slides is kept conveniently, accurately and systematically, the care of the data being entrusted to an archivist.

415, 416 and 417, that is according to the chronological order in which they were performed. These numbers we shall retain, but shall group the cases, not chronologically but according to the operation that was performed. It is appropriate to mention here that the slides and microscopical sections were also systematically arranged and each drawing gives the number of the slide and section from which such drawing was made.

We shall now proceed to the report of our findings in each individual case.

Chapter XVIII.

EXAMINATION OF THE SPINAL CORD AFTER EXTIRPATION OF THE LUMBAR SYMPATHETIC GANGLIA.

Extirpation of the third, fourth, and fifth lumbar ganglia of the left sympathetic cord in a cat of five and one-half weeks. (Case No. 411 of the Institute). Animal killed two weeks after the operation.

Operation.—A longitudinal incision was made in the median line and the abdominal cavity opened in its entire length. The left kidney was drawn forward and turned mesad and ventrad; the peritoneum behind it, which forms the lining of the posterior wall of the abdomen was slit and the opening enlarged upward and downward. The peritoneum was then loosened from the posterior wall of the abdomen towards the median line of the vertebral column, until the sympathetic cord came into view. The two lumbar sympathetic cords lie in close proximity to each other on the bodies of the lumbar vertebræ in a narrow groove formed by the internal borders of the insertions of the psoas muscle. After the left lumbar sympathetic cord had been laid free, it was isolated from the surrounding connective tissue upward and downward; the communicating rami were then severed and a continuous piece of the left lumbar sympathetic nerve, with three of the lumbar ganglia in its course, was resected.

The reason why the operation was performed in the manner described, instead of opening the peritoneum directly in front of the sympathetic nerve, was that so many blood vessels lie in front that one can not reach the gangliated cord without serious loss of blood or without ligation of important blood vessels. According to the procedure adopted by us these blood vessels were entirely avoided and the animal lost only an insignificant amount of blood.

On completion of the operation and after irrigation of the abdominal cavity with sterilized water, the peritoneal and muscular wounds were closed by a continuous catgut suture and the skin wound by a continuous silk suture.

The wound healed by primary union. The animal, lively and apparently well at first, began to appear apathetic, weak, and quite cold after about ten days. Two weeks after the operation it had to be killed; otherwise it would have died in collapse.

Autopsy.—The autopsy revealed entire absence of suppuration, but manifold adhesions. Especially at the site of the gangliated cord numerous adhesions between the intestines and the posterior wall of the abdomen were present. Careful examination showed that the extirpated ganglia were those situated at the caudal end of the third, fourth, and fifth lumbar vertebræ. Whether the lumbar sympathetic cord of the right side was damaged likewise could not be positively determined. In view of the plastic inflammation at the site of the extirpation, it is highly probable, however, that the right lumbar sympathetic cord which lies in close proximity to the left cord, had suffered considerable damage.

In removing the spinal cord, the lower portion of the lumbar enlargement was so bruised by the slipping of the bone forceps that it was rendered unfit for examination. Only the largest part of the third lumbar segment and all the spinal cord from this region upward appeared intact. Of the third lumbar segment the distal half was prepared for Nissl's method, the proximal half for carmine staining and for Marchi's method. The second lumbar segment was prepared in toto for the Marchi procedure, the first lumbar for the Nissl method, and the thirteenth dorsal again for Marchi's method.

Examination of the Specimens Treated by Marchi's Method.—(1).—*Third Lumbar Segment.*—As has been said already, this segment was divided into two pieces; one half of it was put into alcohol in preparation for the Nissl method, the other half in Müller's solution. Of this latter half, a piece was cut off for carmine staining; the remainder was handled in the manner required for Marchi's method. This portion was therefore small and perhaps bruised somewhat. This fact prompts us to a statement of the fact that Singer and Muenzer have shown that trauma can cause the presence of granula in specimens in which there are absolutely no pathological changes. At any rate, every section shows such a large number of black granula in all regions, both of the gray and white substance, that it is very hard to tell which of these granula represent an accidental deposit and which correspond to degenerating tracts of fibres. The findings in the specimen can only be used to confirm the observations made in other segments in so far as a much larger quantity of black granula are found in the course of the posterior root bundles passing through the posterior horn to Clarke's columns, than in any other region.

(2).—*Second Lumbar Segment* (Marchi's Method; see Plate II, Figures 3 and 4).—This segment reveals the changes in a very clear manner. The amount of accidental black granula is small, especially in the gray matter. We can conclude accordingly that where greater accumulations of black granula are present they are manifestations of degeneration going on in the regions concerned. This is still further corroborated by the fact that these accumulations are very constant in their location, being found in the same tracts again and again. But this will become more evident from a detailed description of the conditions found.

In examining a series of cross-sections, one observes tracts of small black granula in the course of the horizontal posterior root bundles as they pass ventrad through the posterior horn (P. R., Plate II, Figures 3 and 4). The granula are to be seen on both sides, but more conspicuously on the left. The root bundles most mesially situated are especially rich in these granula. In a study of serial sections it is observed that these degenerating tracts pass towards Clarke's column of the same side; some are seen emerging from Goll's column, and passing in a straight direction parallel to the median line towards the posterior border of Clarke's column, impinging on the latter at nearly the middle of its transverse extent or somewhat more laterally (P. R., Plate II, Figure 3, on the left side of the picture). On arrival here, the granula seem to disappear. Other, more laterally situated degenerating bundles pass with a forward (ventrad) curve towards the lateral border of the above mentioned cell group. Others, again, still more laterally situated, curve around the external border of Clarke's column and pass to its lower border. This is especially distinct in Plate II, Figure 4, on the left side of the picture (P. R.) Occasionally a bundle passes within the column and seems to distribute itself between the cells, but most of the tracts of black granula are, apparently, arrested at the border of this column. In many sections several bundles or their terminations are encountered simultaneously, in which case a semilunar radiating area of black granula is seen around the external border of the cell group in question, and to a very much less conspicuous degree around the dorsal and ventral borders (Plate II, Figure 3, right side of picture).

In studying serial sections one sees in some of them how tracts of black granules emerge from the posterior columns, and how, in succeeding sections these bundles have moved further ventrad and mesad until finally one sees them ending, apparently, at the border of Clarke's column. In some sections it may be that this border of granula around the cell groups of Clarke's column alone is found, while in the next section, or in the next two or three sections, this border has disappeared.

Occasionally a chain of granula is seen approaching Clarke's column and then passing further ventrad. These latter bundles can be traced only a short distance beyond Clarke's column and seem to end in the area situated laterally of the central canal. Some of the degenerating tracts seen in the posterior root do not take their course towards Clarke's column, but curving off laterad they seem to lose themselves at the base of the posterior horn.

As most of the degenerating fibres in the posterior root bundles seem to stop at the border of Clarke's column, and could not be followed within this cell group, the idea suggested itself that they assumed a longitudinal direction within this group. To determine this point, a continuous series of longitudinal sections was made, passing through both columns of Goll, in a plane at right angles to the dorso-ventral median plane of the spinal cord, as it was thought that when cut in their longitudinal course the fibres would show the granula better than on the cross-section. The results were negative. Only a very small number of granula were found within the vesicular column.

As we found from other evidence (Nissl's specimens) that most of the fibres have their termination in this cell group, the conclusion seemed justified that either the fibres have lost their medullary sheaths on entering within Clarke's column, or that the degeneration being already complete here, the products of the degenerative process have been absorbed. We believed at first that we had found a substantiation of this view in certain vascular changes which will be detailed below. But the value of this evidence is seriously impaired because of the difficulty of distinguishing these alterations from artifacts or changes of entirely post-mortem nature.

A state of hyperæmia was found within Clarke's column and in its vicinity. The blood vessels were dilated and filled with red blood cells; moreover, accumulations of red blood cells looking like capillary hemorrhages were seen. Quite frequently a blood vessel forms the centre of such a focus. It is remarkable that this condition is found almost exclusively in Clarke's columns or in their vicinity, more so in the left than in the right vesicular column. Nowhere else except in the immediate neighborhood of tracts which by the existence of numerous black granula indicate active degeneration, are the hemorrhage-like foci found with such constancy.*

Aside from the degenerating bundles described which as we have seen, are posterior root bundles passing for the most part to Clarke's columns, other tracts show accumulation of black granula with considerable constancy. It has been mentioned that in many sections a semilunar area of granula is observed around the external half of Clarke's column. Sometimes this area of granula is more extended at the ventral border of this column, and quite frequently chains of black granula are noticed emanating from this area and passing in a straight line towards the lateral horn (Plate II, Figure 3, chiefly left side). Whether they end here, entering into connection with the cells of the lateral horn, or whether they pass further into the lateral column can not be decided from the Marchi specimens. It is quite possible, of course, that the fibres were cut so as not to appear in their entire length in one section. The constancy of these changes, however, leaves little doubt that we have to deal with degenerating bundles. We shall have more to say as to the interpretation of this degeneration later.

The anterior roots do not show any evidence of degeneration. Black granula are seen in them occasionally, as also in their irradiations into the anterior horn, but in no larger quantities and with no more constancy than is frequently observed in absolutely normal specimens.

(3.)—*Thirteenth Dorsal Segment* (Marchi's method.)—Examination of this segment still reveals traces of fibre

*As mentioned in the preceding paragraph, the congestion of the vessels and the capillary extravasations may be artifacts. Even the correspondence of the areas of congestion and extravasation with the degenerating fibre tracts and the cell groups which we would expect to be the seat of degenerative processes, may be entirely an accidental circumstance unless they are the expression of disordered vascular innervation because of the lesion of the lumbar sympathetic nerve.

degeneration in the caudal end, and some sections show a focus of hemorrhage in the column of Clarke. In the proximal end of the thirteenth dorsal segment no indications of degeneration are found, and here is therefore evidently the upper limit of the area of degeneration in the fibres.

Examination of the Specimens Treated by Nissl's Method.—(1.)—*First Lumbar Segment.*—Examination of the transverse sections of the first lumbar segment stained by Nissl's method seems to confirm the results obtained with Marchi's method. These specimens show a number of cells in both columns of Clarke in the following condition: The cells appear reduced in size and are deeply stained, many of them appearing as dark, structureless masses. The nucleus and nucleolus seem indistinct, the processes appear to be absent, or, so to say, dried out, showing as dark, thin, tortuous lines. Many cells have the characteristics of Nissl's chromophile cells. From a study of individual sections here and there one might think at first glance that some of these cells had disappeared altogether, since in some of the sections there is a great scarcity of cells in Clarke's column. From a careful examination of serial sections, however, we think that actual disappearance of the cells is questionable. For it is a familiar fact that from the irregularity of the distribution of the Clarke column cells in nests or clusters, sections may be cut between or on the edges of the clusters, and contain but very few cells. It is difficult to say on which side the changes are more marked, but if we compare the findings in a continuous series of from twenty to thirty sections, it seems as if the alterations were somewhat more conspicuous in the left column of Clarke than in the right, but at any rate the difference is not great. This atrophic condition of cells in Clarke's column or its simulacrum (Cl.) is illustrated in Plate III, Figure 6. The same plate, Figure 5, shows for comparison the column of Clarke (Cl.) of a normal cat from the first lumbar segment.

We must not omit to mention that not all cells of Clarke's columns are diseased. Normal cells are seen among the seemingly shrunken ones, and now and then one finds a section in which most of the cells, at least on one side, are normal.* We must add further that the distal end of the first lumbar segment shows almost normal conditions.

A careful inspection of the sections was made to find out whether besides Clarke's columns other cell groups were affected, but the result was negative. Now and then cells of the chromophile type (Nissl) were seen in other regions, for instance in Bechterew's postero-lateral nucleus, around the central canal, and also in the anterior horn. But they were so occasional and so very inconstant that no pathological significance can be attributed to them; especially since, according to Nissl, the existence of a certain number of chromophile cells is consistent with a normal condition. Especial attention was given to the group of cells of the lateral horn, but here also, no decided changes could be made out. Almost every cell appeared quite normal.

The changes in Clarke's column observed in the first lumbar segment diminish, the further one advances

*In making final revision of this whole subject of the lesions in the spinal cord cells in this and the subsequent experiments as demonstrated by Nissl's method we must add some qualifications to our intimation that it indicates a pathological process, or at any rate a well-marked or extensive process. We do think that the changes described in these apparently atrophic cells indicate a pathological process dependent on the removal of one neuron from its secondary annectant neuron. That however is merely our opinion and not the expression of a scientific belief or conviction warranted by sufficient evidence. The question of the nature of the changes in a neuron cut off from its annectant neuron, is very complex, far from settled—and certainly can not be passed upon from a single line of experiments like our own. The question must be left open for future investigations, and in presenting our opinion, we desire to make provision for the contingency that coming researches may demonstrate that the neuron severed from its forerunning neuron, may exhibit only slight and gradual changes or indeed remain apparently in a normal condition for some time. In summing up the changes in these experiments, we find that they are not well marked, and are difficult to make the subject of positive statements.

On the other hand there are a number of observations that tend to substantiate the view that these changes are true pathological lesions. While the fact has been clearly shown, especially by the experiments of Gudden and Forel, that lesion of the neuraxon leads to degeneration in both directions, it is not so well known that degeneration or atrophy may reach beyond the neuron injured and affect the neuron connected with the latter or even a third or fourth neuron. That this may indeed occur seems proven by the observations of Jelgersma, Monakow and others. Jelgersma (Neurolog. Centralblatt, 1895, caudad in the series. Possibly, changes would be still more marked in the thirteenth dorsal segment and perhaps also in the twelfth, but unfortunately no Nissl specimens were made from these segments.

(2.)—*Third Lumbar Segment.*—Of the third lumbar segment the proximal part was stained according to the method of Marchi, and the distal part by Nissl's method. In the proximal portion Clarke's columns are still conspicuous, while in the specimens made from the distal part stained by Nissl's method, the columns have disappeared, and the sections show normal conditions in all the cell groups. It may be remarked here that Clarke's column disappears normally at this level.

To recapitulate the results obtained: Specimens prepared according to Marchi's method show that most of the sensory fibres of the lumbar sympathetic nerve pass toward Clarke's column. The Nissl specimens, revealing as they do degeneration of the cells of Clarke's column, demonstrate on the other hand, that these fibres become connected with the cells of the column of Clarke.

p. 290) enucleated one or both eyeballs in very young pigeons and killed the animals after they had grown up. He then examined the optic nerve, chiasm, and primary optic centres, and found that the lesion had led to destruction of the corresponding optic nerve, chiasm and of those layers of the optic lobe which consisted of a continuance of the optic nerve fibres and the terminal arborization of the same. He found, moreover, atrophy of those nerve cells, the dendrites of which are in intimate contact with the terminal arborization of the optic nerve fibres just mentioned. These nerve cells were reduced in size and altered in structure. This means that enucleation of the eyeball, that is destruction of the first neuron of the centripetal optic pathway has led to atrophy of the second neuron. The details of the cell alterations are not mentioned by the author.

No less convincing are the observations of Monakow, Archiv. f. Psych., V. 24, p. 229, who describes a case in which porencephalia of the right parieto-occipital lobe had given rise to secondary atrophy not only of the primary optic centres: pulvinar, external geniculate body, corpus bigeminum anterius, which were extremely diminished in size, but even of the optic tracts, which were reduced more than one-half, and the left corresponding optic nerve, which was materially narrowed. This and the observations of Schmidt-Rimpler and others, quoted by Monakow prove convincingly that atrophic changes following experimental or pathological lesions may reach beyond the neuron injured. We may therefore understand how the cells of Clarke's column may become atrophic if the terminations of the sympathetic fibres of the posterior roots terminating around these cells become degenerated.

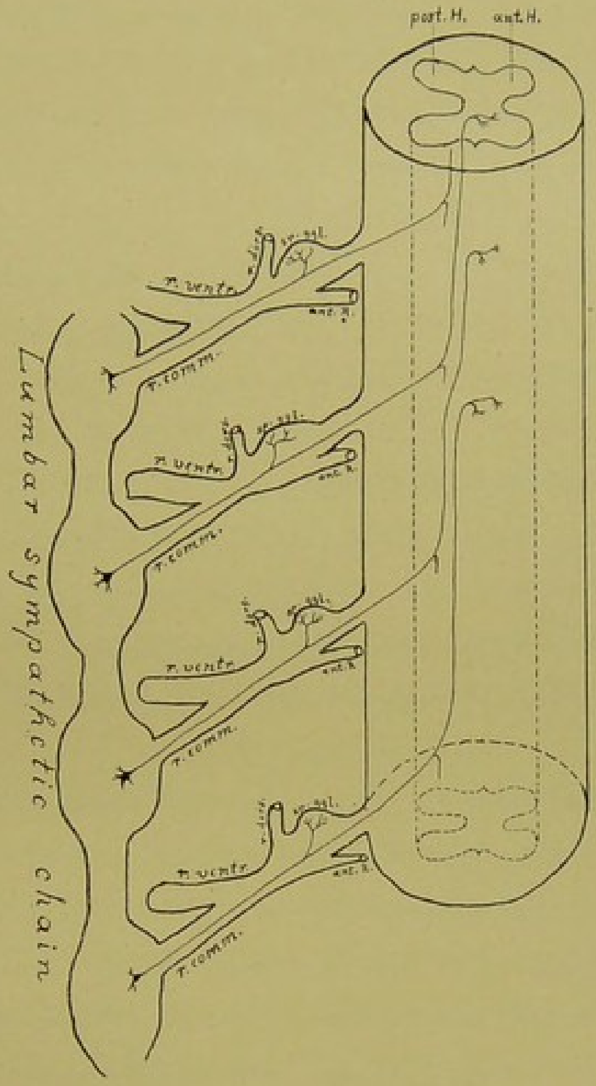
But the investigations of Mott, Cajal, and others, make it almost certain that the cells of Clarke's column send their axis cylinders to the cerebellar tracts and not into the posterior roots. Consequently the connection of the sympathetic sensory fibres with the cells of Clarke's column can only be indirect, that is, through contact or proximity of the terminations of said fibres with the dendrites of these cells or with collaterals of their neuraxons.* The facts noted prove further that most of the sensory fibres of the sympathetic do not originate from cells of the spinal ganglia, as Kölliker claims. On the contrary, they must needs have their cells of origin within the ganglia or plexuses of the sympathetic system. If it were otherwise, we would not have found such extensive degenerations of fibres in the intramedullary course of the posterior root bundles within two weeks after injury to the lumbar sympathetic cord. That the spinal ganglia should have suffered any injury by the operation is out of the question.

In comparing the results obtained by Marchi's method with those given by the Nissl method, we see that the degenerative changes in the fibres cease as we make progression in cephalad direction and end at the level of the thirteenth dorsal segment. They are most conspicuous at the level of the second and probably also at the third lumbar segments. On the other hand, the inferior (caudal) limit of the area of degeneration in the cells of Clarke's columns must be looked for in the first lumbar segment, since in the distal part of this segment scarcely any changes can be discovered. This may be interpreted to mean that the area of degeneration in the fibres occupies a more caudal level than that of the cells to which they belong. We must assume accordingly that the fibres

* See diagrams and accompanying text, page 16, also foot note page 125.

entering the cord by way of the horizontal bundles of the posterior roots make, after having arrived at Clarke's column, a longitudinal course cephalad to end around cells of a considerably higher level. And indeed, if we examine longitudinal sections through Clarke's columns stained according to Pal's technique we can follow longitudinal fibres of this cell group for a considerable distance. Our failure to find degeneration of these longitudinal fibres by means of Marchi's method may have been due to the fact that the fibres are of fine calibre, and that therefore the products of the degenerative process may have been already absorbed. Naturally degeneration will take place quickest where an absolute interruption of continuity in the finer fibres is suddenly created, and this does occur in experimental lesions. In such case it is fair to assume that full degeneration is established earlier in nerve fibres of a *fine* calibre than of a coarse one. Consequently the period during which Marchi's method gives positive results is presumably of shorter duration in the case of fine fibres than in that of coarse. Subsequent experience seemed to confirm this view, inasmuch as in a case of extirpation of part of the thoracic sympathetic nerve, in which case the animal, also a young cat, was killed four weeks after the injury, the spinal fibre-degeneration which evidently occurred could no longer be detected with Marchi's method. It is known on the other hand that in many other cases—in which probably the fibres concerned were coarser—Marchi's reaction is still positive six or seven weeks, if not longer, after the experimental lesion.

To return to our subject, it has previously been mentioned that the degeneration of posterior root bundles passing towards Clarke's column was found not only on



TEXT-FIGURE 5.—Diagram to show the ascent in the spinal cord of the afferent (and probable descent of the efferent) fibres derived from the lumbar sympathetic chain, as resulting from the degenerations following removal of lumbar sympathetic ganglia and described in the text, pp. 127-8.

post. H.—Posterior horn.
ant. H.—Anterior horn.
r. ventr.—Ramus ventralis (—anterior division) of lumbar nerve.
r. dors.—Ramus dorsalis (—posterior division) of lumbar nerve.
sp. ggl.—Spinal ganglion.
ant. R.—Anterior root.
r. comm.—Ramus communicans.

the left (operated) but also on the right side. This involvement of the right side was not due to a crossing of fibres in the posterior commissure, for the degeneration was found in the fibres passing uncrossed from the right posterior column to the right column of Clarke. As no crossing of posterior root fibres takes place within the posterior columns, we must assume, therefore, either that an interchanging of fibres of the right and left side occurs before these fibres reach the spinal cord, or that the fibres of the right side were also injured. Of these two eventualities the latter is the most probable. The two lumbar sympathetic cords are in close proximity to each other, and if we bear in mind that considerable adhesions, the result of plastic inflammation, had been found at the site of extirpation, it seems justifiable to conclude that although only the left sympathetic was operated upon, the right one must have also sustained some injury secondarily.

On the other hand, however, we must remember the existence of the so-called interfunicular rami establishing an interchange of fibres between the right and left sympathetic cords. Thus, an injury of the left sympathetic cord, even if the right cord were absolutely intact, would cause degeneration of fibres in the right posterior roots. But so far as we know, interfunicular rami are of very rare occurrence at the level of the sympathetic cord (3d to 5th lumbar ganglia) at which the operation was performed in our case. Yet the explanation just offered can not be altogether rejected, although we incline more to the view that secondary lesion of the right sympathetic cord, due to plastic inflammation at the site of extirpation, was the main cause of degeneration of posterior root fibres of the right (non-operated) side.

It remains for us to discuss the secondary effect of the lesion of the left lumbar sympathetic nerve on those fibres which join the sympathetic through the anterior nerve roots. In this respect the results were not very satisfactory. The number of black granula found in the intramedullary course of the anterior root fibres was so small that it could hardly be considered as indicative of degeneration. The only tracts (aside from the posterior root bundles) in which accumulations of black granula were found to considerable extent and with much constancy were those which, starting from an area ventrad of Clarke's column, passed in transverse direction toward the lateral column. Only a few fibres could be traced, as it seemed, into this column. Whether the others also reached it or whether they ended in the gray substance of the lateral horn could not be made out positively. Are these tracts to be considered as the continuation of posterior root fibres, which, after passing to the ventral border of Clarke's column, bend off laterally and turn towards the lateral column or lateral horn? Or are they anterior root fibres which originate from cells in the field ventrad of Clarke's column and which instead of joining the anterior roots directly pass first into the lateral column and after remaining in the latter for some distance finally enter the direct horizontal bundles of the anterior roots? The findings of our case are not sufficiently clear to decide this question definitely, but the first hypothesis is more plausible in view of the fact that the anterior root bundles show apparently no degeneration. However, we shall revert to this point in a later chapter.

Chapter XIX.

EXAMINATION OF THE SPINAL CORD AFTER EXTIRPATION OF THORACIC GANGLIA OF THE SYMPATHETIC NERVE.

Extirpation of the sixth, (?) seventh, eighth and ninth thoracic ganglia of the right sympathetic nerve, together with the intervening internodial rami and the adjoining portion of the splanchnic nerve of a cat six weeks old. (Case No. 417 of the Institute). Animal killed four weeks after the operation.

Operation.—Under ether narcosis a long incision was made over the course of the right seventh rib. The muscles of the seventh intercostal space were exposed and severed by an incision beginning at the spinal column and extending about one to one and one-half inches along the intercostal space. Narcosis was occasionally interrupted so that the animal could better withstand the effects of the pneumothorax. The opening into the pleural cavity was widened by pulling the ribs apart with blunt hooks. In order to secure satisfactory illumination of the field of operation the light of a lamp was thrown in by means of a reflector. The sympathetic cord which is covered by the costal pleura was then exposed for some distance upward and downward and while one of us raised the nerve with a blunt hook, the other severed the rami communicantes and resected a continuous piece of the cord with three of the ganglia and the adjoining portion of the splanchnic nerve. The skin wound was then coapted with a continuous silk suture. The animal recovered speedily from the effects of the operation. In a few days the pneumothorax had entirely disappeared and on removing the sutures it was found that the wound had healed by primary union. The animal was killed with chloroform four weeks after the operation.

Autopsy.—The autopsy notes read as follows: Right lung adherent in lower part. Both lungs have a speckled appearance, which seems due to pigmentation. Examination of the site of extirpation shows that the resection of the right sympathetic nerve (with the ganglia and splanchnic nerve) extended from the sixth down to the ninth intercostal space, including the sixth (?), seventh, eighth and ninth thoracic ganglia. The seventh right intercostal nerve appeared swollen in a small circumscribed area. The primary cause of this swelling was probably pressure of the tenacula during the operation.

Technique of Fixation.—The fifth and sixth dorsal segments of the spinal cord were prepared for examination by Marchi's method; the seventh dorsal for Nissl's procedure. Of the eighth dorsal one-half was taken for the Nissl and one-half for the Marchi technique, the same being done with the ninth dorsal, while the tenth was examined with the Nissl method alone. The various segments were studied in continuous series of transverse sections, each series numbering between twenty-five and eighty sections. Instead of reporting individually the findings in each segment, we shall give a combined report of the condition as found in all the Marchi specimens, and another embodying the results of study of the Nissl specimens. We were, of course, aware of the fact that the findings in the seventh segment would have to be interpreted eventually with great caution, since the whole seventh intercostal nerve had suffered some injury, but fortunately two (or three ?) additional ganglia had been extirpated besides the seventh.

Examination of the Specimens Treated by Marchi's Method.—The segments examined with this method were the fifth, sixth, eighth, ninth and tenth dorsal. In all these segments examination reveals the almost entire absence of black granula indicative of degeneration. Now and then black granula are found within the course of posterior root bundles and around Clarke's column, as well as in other regions; but their number is so small that they give us no clue in following the course of diseased fibre bundles. However, a peculiar condition is present, similar to that observed in the animal in which a part of the lumbar sympathetic had been resected, and which had been killed two weeks after the operation. The condition referred to consists in the presence of hemorrhagic foci. These foci consist of agglomerations of red blood cells, the centre of which in many instances is occupied by a transversely cut blood vessel. Where the blood vessel is cut longitudinally, the blood cells are seen on both sides of it occupying the perivascular space; or covering it almost entirely so that the blood vessel can scarcely be distinguished. In many of the foci no blood vessel is seen.

As to the location of the foci, we find them predominantly in definite regions, but principally in the margin of Clarke's column, in the course of the mesial bundles of posterior root fibres, in the area laterad of the central canal, and in the neighborhood of the anterior commissure. Some are seen also in the posterior column between the columns of Goll and Burdach, at the point where the corresponding root bundles enter the posterior horn. Finally, there are a few which show quite a characteristic arrangement. In some sections, for instance, one long focus seems to extend from the area ventrad of Clarke's column toward the lateral horn; in another section a focus starting at the anterior commissure seems to tend toward the lateral horn; and, finally, one or two others are seen forming a prolonged tract within those posterior root bundles, which, passing through the base of the posterior horn, seem to direct themselves toward the region of Bechterew's nucleus at the lateral border of the base of the posterior horn.

The changes just mentioned are most conspicuous in the eighth dorsal segment, but they are also distinct in the ninth and sixth segments, while in the fifth they have almost entirely disappeared. They are seen on both sides of the cord, though less numerous on the left side.

The eighth dorsal segment was allowed to remain in connection with the spinal ganglion on the right side, so that a continuous series of sections of the latter was obtained. In one of these sections of the spinal ganglion a hemorrhagic focus is also found. It is situated in the centre of the area which forms the irradiation zone of the posterior root fibres into the ganglion. From the fact that such a focus was found in only one section it seems of but little significance.

Examination by Nissl's Method.—The segments examined with Nissl's method were the seventh, ninth and tenth dorsal. Sections of these segments also presented distinct changes in Clarke's columns. Some of the cells had disappeared entirely; others show atrophic changes of different degrees: shrinkage of the cell body and processes, loss of the chromatic structure so that the cells appear as dark, structureless masses, presenting in short, changes similar to those observed in the animal in which a piece of the lumbar sympathetic nerve with the ganglia had been extirpated.

It appears, moreover, as if there was a scarcity of the small cells grouped around the central canal, but this is not sufficiently marked to justify a positive statement. It seems, further, as if the small cells of the lateral horn showed some alterations, especially on the operated side, but not enough to be recognized distinctly as pathological.

The changes described in Clarke's columns were more pronounced on the operated side, but the difference between the two sides is not considerable. A fair number of normal cells are observed among the degenerated ones, but in the majority of the sections examined the number of apparently diseased cells surpasses the number of normal ones.

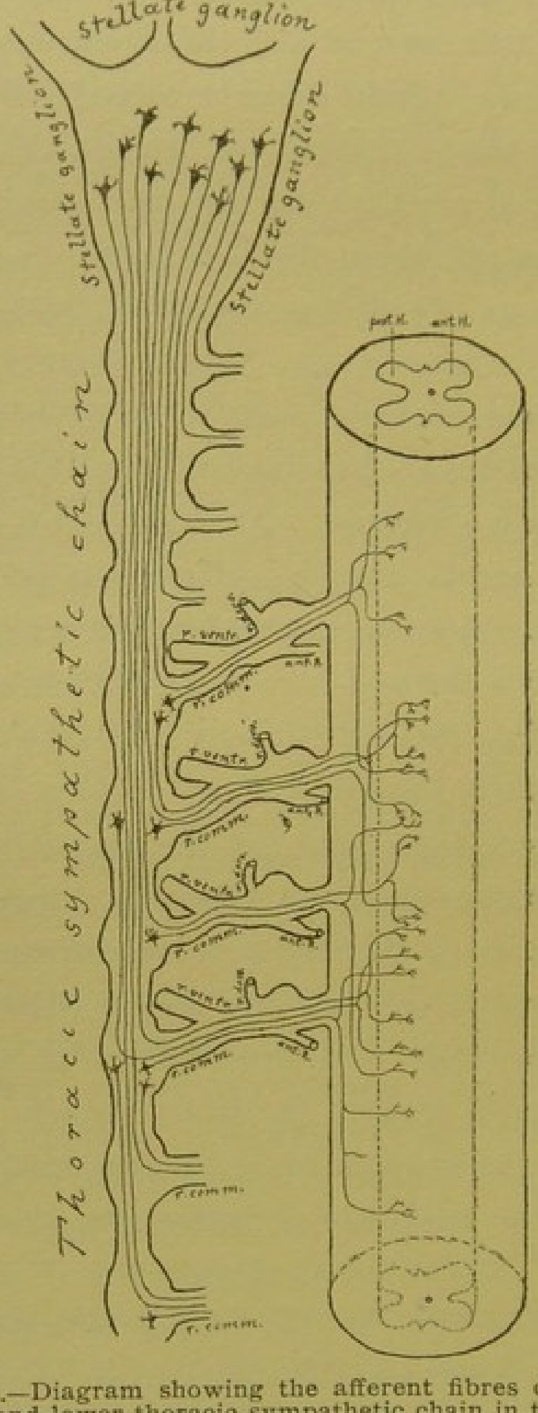
The cell alterations in Clarke's columns were present in all the segments examined, that is, in the seventh, ninth and tenth dorsal. They do not seem to be more prominent in one than in another. In the seventh dorsal segment the number of cells is smaller, but this is also the case in normal specimens, in which the number of cells increases from the seventh downward.

We must add that despite the swelling of the seventh intercostal nerve found at the autopsy of the operated animal, the seventh dorsal segment shows only very slight changes which might be attributed to lesion of the "somatic" fibres of the nerve. Now and then some of the large anterior horn cells are found altered, but this is noted also in the ninth and tenth dorsal segments.

To reiterate and summarize, we find that four weeks after the extirpation of three (or four ?) thoracic sympathetic ganglia, the secondary changes wrought in the spinal cord can be no longer traced with Marchi's method. The sections, however, reveal the presence of numerous foci of diapedesis. Shall these be considered as a reaction of the healthy tissue destined to remove the products of degeneration; or are they the outcome of vasomotor disturbances brought about by the lesion of the thoracic sympathetic; or, finally, as intimated in a foot-note of the preceding chapter, are those changes merely the outcome of post-mortem congestion or other artifacts ? We hardly feel justified to answer these questions before more evidence is collected. At any rate it is interesting to note that they are confined to a circumscribed region of the spinal cord, a region corresponding rather closely to that in which the cellular and fibre degeneration was found.

With regard to the cell changes in Clarke's column, the observations made for the lumbar portion of the sympathetic cord were confirmed for the thoracic portion, and here again the changes were bilateral, although here the lesion was confined decidedly to one sympathetic cord, namely, the right, the left one being absolutely intact. As no interfunicular branches connecting the two sympathetic cords are present in their thoracic portions, the bilaterality of the changes must be explained by a crossing of fibres in the posterior commissure, or directly from one column of Clarke to the other.

In view of the fact that the *cellular* changes in Clarke's column were rather equally distributed over the (sixth ? not examined with the Nissl stain), seventh, (eighth ? not examined with the Nissl stain), ninth and tenth dorsal segments, it is fair to conclude that on the whole the sympathetic fibres from the (sixth), seventh, eighth and ninth sympathetic ganglia—*i. e.*, those extirpated in our animal—take a rather horizontal course in the spinal cord (see Text-Figure 6). Some of these fibres make a slight descent in



TEXT-FIGURE 6.—Diagram showing the afferent fibres derived from the stellate ganglion and lower thoracic sympathetic chain in their course to the spinal cord. The course is suggested by the degenerations following removal of the stellate ganglion and also the lower thoracic sympathetic chain. The efferent fibres very likely have a similar course in opposite direction.

post. H.—Posterior horn.
ant. H.—Anterior horn.
r. ventr.—Ramus ventralis (anterior division) of dorsal nerve.
r. dors.—Ramus dorsalis (posterior division) of dorsal nerve.
ant. R.—Anterior root.
r. comm.—Ramus communicans.

the spinal cord, since marked changes were found in the cells of Clarke's column of the tenth segment, although the extirpation of the thoracic sympathetic nerve extended downwards only to the ninth intercostal space, leaving the communicant ramus of the tenth dorsal nerve unaffected. This conclusion requires a certain restriction in view of the fact that a piece of the splanchnic nerve was resected together with the thoracic sympathetic ganglia; but we remind the reader of our experience in a case of resection of the semilunar ganglion in a young cat, an operation which implies lesion of the splanchnic nerve. Yet the examination of the spinal cord of this cat, which was allowed to live twenty days after the operation, failed to reveal any undoubted fibre or cell changes. We admit, however, that the examination of this spinal cord was not as extensive and systematic as in the other cases, being made more for the purpose of orientation: a tentative examination, so to speak. Therefore no very positive conclusions can be drawn from the negative character of the findings.

To return to the case of extirpation of the thoracic sympathetic ganglia, examination of the different series had led us to suspect that the cells situated on both sides of the central canal ("paracentral" groups, see p. 140) and those of the lateral horns were also affected, but we could not come to a positive conclusion. As, however, we had performed the same operation previously, in another animal, which was allowed to live for six months, we had hopes that in the latter case the ascending degeneration in the efferent fibres, and especially in their cells, would be so distinct as to elucidate points left obscure by the examination of the specimens described above. For, as has been said already, we suspected that the cells of the lateral horn and those situated to both sides of the central canal (paracentral group) were of the motor order, and we should expect more marked secondary changes in these cells if the lesion of the efferent fibres producing the secondary changes took place several months before the death of the animal, than if only three or four weeks elapsed between the date of operation and of death. We shall, accordingly, continue our report with a description of the condition found in this case.

Extirpation of the eighth, ninth, tenth and eleventh thoracic ganglia of the right sympathetic cord, together with the intervening internodial rami and the adjoining piece of the splanchnic nerve, in a cat of five or six weeks. (*Case No. 415 of the Institute*). *Animal killed six months after the operation.*

Operation.—The operation was performed in the same manner as in the preceding case. The resulting pneumothorax produced disappeared in three days. The wound healed by primary union. Six months after the operation the animal was killed with chloroform.

Autopsy.—The post-mortem examination showed that the eighth, ninth, tenth and eleventh thoracic ganglia had been extirpated, that is those situated in the eighth, ninth, tenth and eleventh intercostal spaces respectively. Only slight adhesions of the lung were present in the region where the thorax had been opened; otherwise the lungs looked quite healthy. There was no pus or cheesy degeneration anywhere.

Nissl Specimens.—The tenth and thirteenth dorsal segments were studied each in a series of transverse sections. The eleventh and twelfth dorsal were left in connection with each other, and a longitudinal series was made, the plane of section being vertical to the median plane of the spinal cord, and parallel with its longitudinal axis. For comparison, a longitudinal series of the same description was made through the eleventh and twelfth dorsal segments of a normal adult cat. This was important, as experience had taught us that the changes were bilateral, and would therefore become more evident by comparison with a normal specimen. The other segments of the spinal cord of the operated animal were not examined. As the morbid conditions were particularly clear in the series of longitudinal sections, we shall begin first with a description of the latter.

Longitudinal series through the eleventh and twelfth dorsal segments. Plane of section vertical to the antero-posterior median plane of the spinal cord.

(1).—*Clarke's Columns.*—To comprehend the picture presented by these two cell groups, it must be remembered that in the cat the columns of Clarke are placed directly dorsad of the central canal, one on either side, bordering the median plane of the cord. In the longitudinal sections we are considering now, the two columns of Clarke are thus united into one longitudinal strip or band. In such sections the chromatic structure of the cells composing this group reveals itself strikingly and the chromophilic plaques present themselves as long stripes directed parallel to the longitudinal axis of the cell. This is especially marked in the larger cells and nowhere else have we found this parallel striped arrangement so typically developed. Mott has called attention to the presence in Clarke's columns of two types of cells, large ones and small ones. We can corroborate this distinction, implying by it that among the large cells there is a great variation of size; medium large, large and true giants. All the cells of the column have a tendency to spindle shape. Of the small cells of Clarke's column we must add that many of them approach the type of the cells of the paracentral group. But to return to our subject. In comparing Clarke's columns of the normal cat with those of the operated animal, we recognized considerable retrogressive changes in the latter. These changes are of an atrophic order, and are present on both sides. It is difficult, nevertheless, to say which side is most affected, though the right side seems more so than the left. The small cells are on the whole more altered than the large ones, but the latter are distinctly shrunken.

(2).—*Cells of the Lateral Horn* (see Plate V, Figures 9 and 10).—Normally, this cell group is well developed in the lower dorsal region. The characteristic elements are the small spindle-shaped cells. This spindle shape is most striking in the longitudinal sections, for the cells are encountered in their long axis (Plate V, Figure 9). In the cervical and lumbar regions the lateral horn is occupied not only by the cells just mentioned, but also by groups of large cells which belong to the type of the anterior horn cells, whereas in the lower dorsal region the small cells alone are seen. The group is thus represented by a very pure type in the lower dorsal region. In longitudinal sections it does not appear in the form of a continuous column, but segmented, in the form of cell nests distributed at intervals (Plate V, Figure 9).

In the operated animals we find a marked difference in the two sides. The cells of the right lateral horn, on the whole, seem smaller than those of the left lateral horn, and they appear shrunken (see Plate V, Figure 10). The atrophic changes are most apparent when comparison is made with a normal specimen. Then it is seen that the cell group is diseased on both sides. In the normal specimen the cells have a full cell body, with well rounded contour. In the cells of the operated animal the cell body is small, slender, twisted, with attenuated and somewhat tortuous processes. Closer inspection shows, in a measure, what may be described as an alternate involvement; that is, in the same lateral horn one group is found relatively normal, the next one or two much diseased. This condition is observed on both sides, but, as has been said already, the group of the right side is more affected than that of the left.

(3).—*Paracentral Group.*—This name we wish to give to a well marked cell group which to our knowledge has not been described and which we have studied both on transverse and longitudinal sections. It is situated ventrad of Clarke's column, on each side of the central canal—for this reason the designation "paracentral" has been chosen (Plate IV, Figure 8, parc.) The longitudinal sections show the group to be segmentally arranged in nests distinctly distanced from each other (Plate V, Figure 11). It is composed of cells much smaller than the average anterior horn cells, yet showing some analogy in the chromatic structure, *id est*, a tendency to parallel striped arrangement of the Nissl bodies. The cells are for the most part spindle-shaped—although rather broad in their transverse diameter—and their longitudinal axis is usually placed parallel to the longitudinal axis of the cord (Plate V, Figure 11). The paracentral groups are very prominent in young animals and are frequently blended with the cell groups of Clarke's column (Plate IV, Figure 7, parc.) Many cells of the latter bear great resemblance to those of the paracentral group both in size and shape.

In man this group seems indeed to have lost its individuality and to form part of Clarke's column except in certain levels, namely, the upper dorsal and middle sacral region where a cell group is seen which apparently corresponds to the paracentral group although situated considerably more laterad than in the cat.

In our operated animal the changes found in this group, showing well in the longitudinal series, may be summarized as follows: On examining in successive order all sections passing through the central canal, we find that on the whole the cell nests grouped to the right side of the canal are apparently smaller and numerically diminished as compared with those on the left side. (See Plate V, Figure 12; compare with normal group, same plate, Figure 11). This series of sections was submitted to our colleague, the late Dr. A. Graf, Associate in Biology at the Institute, for examination, and he verified our statement, although he was not aware of the side on which the operation had been performed. The abnormality of this cell group becomes still more apparent when we study them in comparison with the paracentral group of the normal animal. Here the group is segmented and arranged in the form of cell nests. The cells are on the whole rather small, but they have a well defined chromatic structure, with a tendency to parallel-striped arrangement of the plaques.

If now we return to the examination of the series made from the operated animal, we find that this group is not only altered on the right side, but also on the left. The most striking feature is the smallness of the cells. Although many of them, if examined *per se*, could not be recognized as pathological, we find them when compared with the cells of the normal series, distinctly reduced in size. Aside from cells which seem only reduced in size, we find a number of others with alterations in their chromophile structure. They seem more deeply stained than other cells, and the chromophile substance appears distributed in an irregular manner, presenting itself in the form of large fragments. Such elements are seen in the paracentral cell groups of both sides, more distinctly on the right.*

(4).—*Intermediate Zone.*—By this designation we imply the region which borders laterad the cell group of the lateral horn, mesad the paracentral cell group, dorsad the posterior horn, including the base of the latter, and ventrad the base of the anterior horn. In our longitudinal series the zone thus called is comprised between the plane of section which passes through the ventral border of the posterior column and the plane of section passing in front of the central canal. The cells of this zone are, for the most part, small, approaching in shape and structure the cells of the lateral horn and of the paracentral group. Many of them are exquisitely multipolar. Aside from the small cells a limited number of large ones are seen. Some of them make the impression of being cells of Clarke's column which have strayed away into the intermediate field. Such cells are encountered chiefly in the dorsal parts of the zone described. Others are typically multipolar. The large cells are for the most part scattered irregularly, but in some sections they are collected into a group.

In our operated animal the whole intermediate zone appears affected, the changes consisting in shrinkage of the elements, which is more striking in the small cells,

* The reservations stated in a previous chapter relating to this subject should be recalled here.

although the large ones also seem distinctly shrunken, and again the changes are bilateral.

Tenth and Thirteenth Dorsal Segments (*Transections*).—Of these segments only transverse series were made. It seems superfluous to dwell at length upon the changes here found and we shall content ourselves in saying that both segments presented marked bilateral alterations in Clarke's columns, in the cells of the lateral horns, in the paracentral groups and in the intermediate zone. In short they showed, although not in such a striking manner, the conditions described as occurring in the twelfth dorsal segment. We may add that the intermediate zone comprises also Bechterew's nucleus, situated between the lateral horn and the base of the posterior horn. This nucleus was found to be distinctly altered.

Study of the two cases last described makes it very probable that topographically the spinal cells which are connected with the seventh to the eleventh thoracic sympathetic ganglia are situated in part at corresponding levels, and in part at lower levels. In other words, part of the visceral fibres, at least those of the afferent class, probably also part of the efferent fibres coming from the lower thoracic sympathetic cord, descend through a distance of one or two, perhaps even more, segments of the spinal cord before reaching their termination or their cells of origin (see Text-Figure 6, p. 136).

Furthermore it appears that the sympathetic fibres present in the rami communicantes of the lower portion of the thoracic sympathetic cord are connected, not only with the cells of Clarke's columns, but also with the cells of the paracentral group, of the lateral horn and of the intermediate zone. Finally, the connection seems invariably bilateral. That Clarke's cells are connected with the afferent fibres appears from the observations made in the first case (No. 411). We shall speak in another chapter of the relation of the cells to the fibres of the other groups and now proceed to give a report of the cases in which the stellate ganglion was extirpated.

Chapter XX.

EXAMINATION OF THE SPINAL CORD AFTER EXTIRPATION OF THE STELLATE GANGLION.

Extirpation of the left stellate ganglion in a cat of about two months (Case No. 414 of the Institute) and of the right stellate ganglion in a cat of six weeks (Case No. 416 of the Institute.) Animals killed three and five months respectively after the operations.

Observations were made on two cases, and for convenience sake we shall report them conjointly, beginning with a description of the conditions found in the spinal cord, reserving the report of the changes in the oblongata of these animals for another chapter.

Operation.—In previous experiments we tried to reach the ganglion from the ventral side, that is by making a deep dissection of the neck anteriorly down to the vertebral column. The attempts were futile, because of the deep situation of the ganglion—between the first and second ribs—and because the œsophagus, which had to be loosened from the neighboring tissue, puffed up balloon fashion with nearly every respiration and thus persistently hid the field of operation. The obstacles mentioned were so great that every trial to reach the ganglion had been in vain. It was therefore resolved to approach the ganglion from behind instead of from the ventral side, which was done in Cases Nos. 414 and 416 in the following way:

A longitudinal incision of the skin about one and one-half inches long was made in the lower part of the neck and the upper part of the dorsal portion of the spine. From the middle of the wound a transverse incision of about the same length was then made. The two triangular skin flaps thus formed were then loosened from the underlying tissues. This done, the muscles connecting the internal border of the scapula with the spine were severed. The scapula was thus pushed laterad exposing the first and second ribs. It should be mentioned that during these manipulations no nerve branches were encountered. The left pleural cavity was now opened by cutting the intercostal muscles along the edge of the second rib. The opening thus made was widened by pulling the first and second ribs apart by means of two tenacula shaped similar to lid retractors. The ganglion which is situated in the groove between the external border of the scalenus posticus muscle and the rib was then easily found, pulled out with a Wecker's double hook and removed by severing all of its connections. When the thorax was opened, the character of the respirations became, of course, profoundly altered; they grew very deep and slow. When the connections of the ganglion were severed the animal manifested distinct signs of commotion (although fully anæsthetized). After the extirpation the outer wound was closed by means of a continuous silk suture.

In the cat designated as Case No. 414, the wound had to be reopened the day after the operation as it was discovered that a piece of the first intercostal nerve had been resected instead of the stellate ganglion. At the second operation the stellate ganglion was removed, the animal withstanding the operation very well.

In the other animal the stellate ganglion was removed without difficulty or mishap. In both cases the sutured wound reopened and union took place by granulation.

Autopsies.—The autopsy made three months after the double operation in Case No. 414 showed that the first intercostal nerve resected by mistake at the first operation had apparently regenerated although it was still considerably thinner than its fellow of the other side.

There was, however, complete defect of the left stellate ganglion and of the sympathetic nerve down to the second intercostal space.

The second animal (Case No. 416) was killed five months after the operation, and the post-mortem examination showed defect of the right stellate ganglion down to the third intercostal space. In neither case was there any suppuration or cheesy deposits at the site of extirpation.

Nissl Specimens.—(*1*).—*Transections. Clarke's Column.*—The segments examined in transverse series were the seventh cervical and the first, third, fifth, seventh and ninth dorsal. There was apparently considerable involvement of all the dorsal segments shown in a shrinkage of both columns of Clarke wherever these are present. We must add that the presence of the vesicular columns is evidenced by the shape of the gray matter and especially the part situated between the central canal and the ventral border of the posterior horn being very wide. When Clarke's columns are disappearing, the space between the central canal and the ventral border of the posterior columns becomes smaller and at the level of the first dorsal the posterior column is separated from the central canal only by a narrow bridge of gray matter, and Clarke's column can no longer be found in this segment. In the third dorsal segment it can be recognized as a group while in the fifth and seventh it becomes still better defined, reaching a high degree of development in the ninth dorsal segment. It will be understood, therefore, that if changes were present in this column throughout its extent from the third to the ninth dorsal, such should be most distinct in the ninth dorsal; and this was exactly the case in our experiment.

Lateral Horn Cells.—In all of the dorsal segments just mentioned, the cells of the lateral horn are profoundly affected and more on one side. It would seem natural to assume that the side showing the greatest lesion was the affected side, but in the first dorsal segment, where the sides were marked, it looked on the contrary, as if the groups of the operated side were less involved than those of the other side. This impression was conveyed also on examining the first dorsal segment cut in longitudinal series of the other operated cat. We do not wish to make a positive assertion concerning this however. One can easily be mistaken, since at this level the cells do not form such a compact, well defined group as they do lower down in the cord. They begin to lose themselves in the processus reticularis and are even encountered, in a scattered fashion, amongst the cells of the lateral column. In this manner asymmetries of the group may occur even in the normal animal. Above this, in the seventh and fifth cervical segments, the irregular distribution of these cells becomes still more manifest and it was impossible to form a positive opinion as to the condition of the group at these levels especially since no normal series of these segments were at hand for control and comparison.

Paracentral Group and Intermediate Zone.—The paracentral group is present in all the dorsal segments; in the fifth and seventh cervical it appears well defined. In our operated animals it seemed shrunken on both sides in the dorsal segments. As to its condition in the fifth and seventh cervical segments we do not care to venture a positive assertion, no more do we in reference to the intermediate zone of which it is very difficult to form an opinion from sections of a transverse series.

(2.)—*Longitudinal Series Through the Eighth Cervical and First Dorsal Segments.*—This longitudinal series vertical to the median plane of the spinal cord and parallel with its longitudinal axis was made with the special view of studying the position of a functionally indicated ciliospinal centre, as experience with the cat registered as Case No. 415 had shown that longitudinal sections gave the best conditions for the identification of this suspected centre. For comparison, a longitudinal series of a similar kind was made from a normal cat. The cells that showed changes were confined to the paracentral group and the group of the lateral horn. In the paracentral group there were found marked atrophic changes on both sides, more pronounced on the right. These changes are more evident in the longitudinal series than in transverse sections, because the total chain of the cell nests appears in one and the same section. In reference to the group of the lateral horn we refer to what has been said concerning it in the report of the transverse series.

It is difficult to judge of the cells of the intermediate zone, as the zone is much less distinct in its cellular composition here than it is in the dorsal region. This makes it difficult to trace those elements which we have met with in the lower dorsal region. On the whole it is our impression that in the eighth cervical and first dorsal segments the intermediate zone was normal.

Specimens by Pal's Method.—Fibres of Clarke's Column and the Paracentral Field.—We had hoped that a series stained according to Pal's method would demonstrate the presence of atrophic changes of the root fibres, and that in this manner we could determine with which cells or cell groups the various sets of visceral or "vegetative" fibres were connected, more especially those of the anterior roots. We were disappointed. The bilaterality of the changes made it quite impossible to distinguish the course of fibre tracts by their atrophy. But the series thus stained gave us information as to the course of certain fibre tracts which, however, might have been gained as well in all probability from a study of normal specimens. An extensive series of transverse sections through the eighth dorsal segment in Case No. 414 (see p. 144 *et seq.*) showed the following conditions:

In the first place many horizontal bundles of fibres which often can be traced as coming from the posterior columns are seen entering Clarke's column and, arriving here, bend off in vertical direction and continue as longitudinal fibres of the vesicular column (Plate VI, Figure 13, P. R., P′ R′, see attached diagram for orientation). It can not be proven, but is highly probable from our former findings, that part of these fibres at least are the direct continuation of posterior root fibres. Again, one sees now and then a horizontal bundle, apparently of the posterior root, enter Clarke's column and split up within the cell group as if to end there.

Let us now take a look at Plate VI, Figure 14. It shows on the left side of the picture two round fibre areas; one is Clarke's column (Cl.), the other we call the paracentral field (PARC.) It will be seen that the position of this paracentral field corresponds rather closely to that of the paracentral group although it lies in part somewhat more lateral. These two fields (Clarke's column and the paracentral field) show intimate relations to each other. In the first place fibres coming apparently from the continued mesial bundles of the posterior root penetrate through Clarke's column and give the impression of terminating in the paracentral field, or of becoming vertical fibres of the latter. Secondly, vertical fibres of the paracentral field are seen bending off into horizontal direction and entering Clarke's column. In Plate VII, Figure 15, such a bundle (rfl.) is seen (see attached diagram for orientation); some of its fibres after having arrived in Clarke's column bend off at a right angle, becoming vertical fibres of this column; others pass possibly further dorsad. Vice versa (on other sections) vertical fibres emerging from Clarke's column are seen bending dorsoventrad to pass into the paracentral field; part of them proceed further toward the anterior horn, others seem to lose themselves within the paracentral field, and the impression of their ultimate connection with the latter becomes strengthened by the fact that in the following sections numerous obliquely cut fine fibres make their appearance in the field named. Plate VII, Figure 16, is especially illustrative. Here two vertical bundles are seen in Clarke's column; one bends off dorsad in the direction of the continued posterior root bundles, the other deflects itself toward the paracentral field where some of the fibres become again vertical, thus contributing to the constitution of the paracentral field (compare with attached diagram). Again (on other sections) one sees long horizontal bundles passing from the ventral part of the anterior horn (anterior root fibres ?) toward the paracentral field and they appear to pass partly into the latter and partly into Clarke's column.

In Plate VIII, Figure 18, which represents a longitudinal section passing through Clarke's column and through the paracentral field (I lumb. segm. of Case No. 415), we observe a rich mass of extremely fine fibres. This could only be hinted at in the said figure where PARC. represents the paracentral field; but the fineness of fibres is so exquisite that we feel almost justified in assuming that part of them split up and terminate here. From what has been said before, it would further seem very probable that these fine fibres of the paracentral field are for the most part derived from Clarke's column, and partly perhaps, directly from posterior root fibres.

In the same section from which Plate VIII, Figure 18 was taken, and which was stained according to Pal's method and restained with fuchsine, we were fortunate enough to observe the termination of a nerve fibre on the cell-body of a cell of Clarke's column; at least we could not give any other interpretation to the picture seen which we have illustrated in Plate VIII, Figure 17. Here a fibre (f.) coming from below is seen passing along the cell body C.B. of a cell, appearing as a black line. Arrived at a certain point, it expands, takes on deeper coloring and terminates with an oval finely granulated disc (d.) of light red color (about the same color as the remainder of the cell body). This picture of the fibre with its terminal disc is quite similar to the pictures obtained by Huber with Ehrlich's methylen blue in vivo-stain. (See Anatomischer Anzeiger, 1896, Vol. XII, pp. 420, 421, Figures 1 and 2). Huber made his observations on the spinal ganglia of amphibia and the terminal discs which he saw were the endings of collateral twigs from the axis cylinder of the very same cell on which the said twigs terminated. In our case it seems improbable that the terminating fibre is a collateral of the axis cylinder of the cell on which it terminates; it is much more likely the terminal twig of a sympathetic afferent posterior root fibre.

Results of Extirpation of the Stellate Ganglion.—In summarizing the results of our observations on the spinal cord of cats in which a stellate ganglion had been removed we find that the removal of this ganglion causes within a few months retrogressive changes of an atrophic order in the cells of both lateral horns, of both paracentral groups and of both columns of Clarke. These changes extend downward at least to the ninth dorsal segment, and since they are secondary to changes of the fibres of the ganglion we are justified in assuming that many of these fibres make a long descent in the spinal cord, or possibly in the sympathetic nerve, becoming connected partly with the same cells with which the fibres from the lower portion of the thoracic sympathetic cord are connected (see Text-Figure 6). That some restriction in accepting the latter part of this conclusion is necessary is shown by the fact that in the two cases in which thoracic ganglia were removed part of the splanchnic nerve was resected at the same time. This matter has been discussed on p. 137. It is possible also, that many of the cerebrospinal fibres of the stellate ganglion are derived from or pass into rami communicantes of the lower part of the thoracic sympathetic in which case extirpation of the stellate ganglion might lead partly to the same spinal cell changes as extirpation of the lower part of the thoracic sympathetic nerve.

Finally we must bear in mind another possibility. According to Ramon y Cajal the fibres of the posterior roots after T shaped division become ascending and descending and send off collaterals which terminate either around the cells of the substantia gelatinosa or around the cells of Clarke's column. In this case those passing to Clarke's column are afferent sympathetic nerve fibres—and there seems no doubt from our obervations in Case 411 (Extirp. of lumb. symp. ggl.) that many of them are. It is, therefore, quite likely that many of the afferent fibres of the sympathetic after T shaped division become ascending and descending, sending off collaterals at various levels and thus become connected with several levels of Clarke's column simultaneously. We know on the other hand from the investigations of Sala, Kölliker and others, that the efferent cerebro-spinal fibres encountered in the sympathetic system send off collaterals at various intervals. We can easily imagine that by extirpation of one particular sympathetic ganglion only one or two such collaterals become severed and that the other branches of such fibres remain intact. In this way we could understand, why in young animals operated upon by us the cells of origin of these fibres in the spinal cord did not undergo within months after extirpation of a ganglion of the sympathetic chain, as profound atrophy as we find in the typical motor nerve nuclei several months after severance of the corresponding motor nerve.

Chapter XXI.

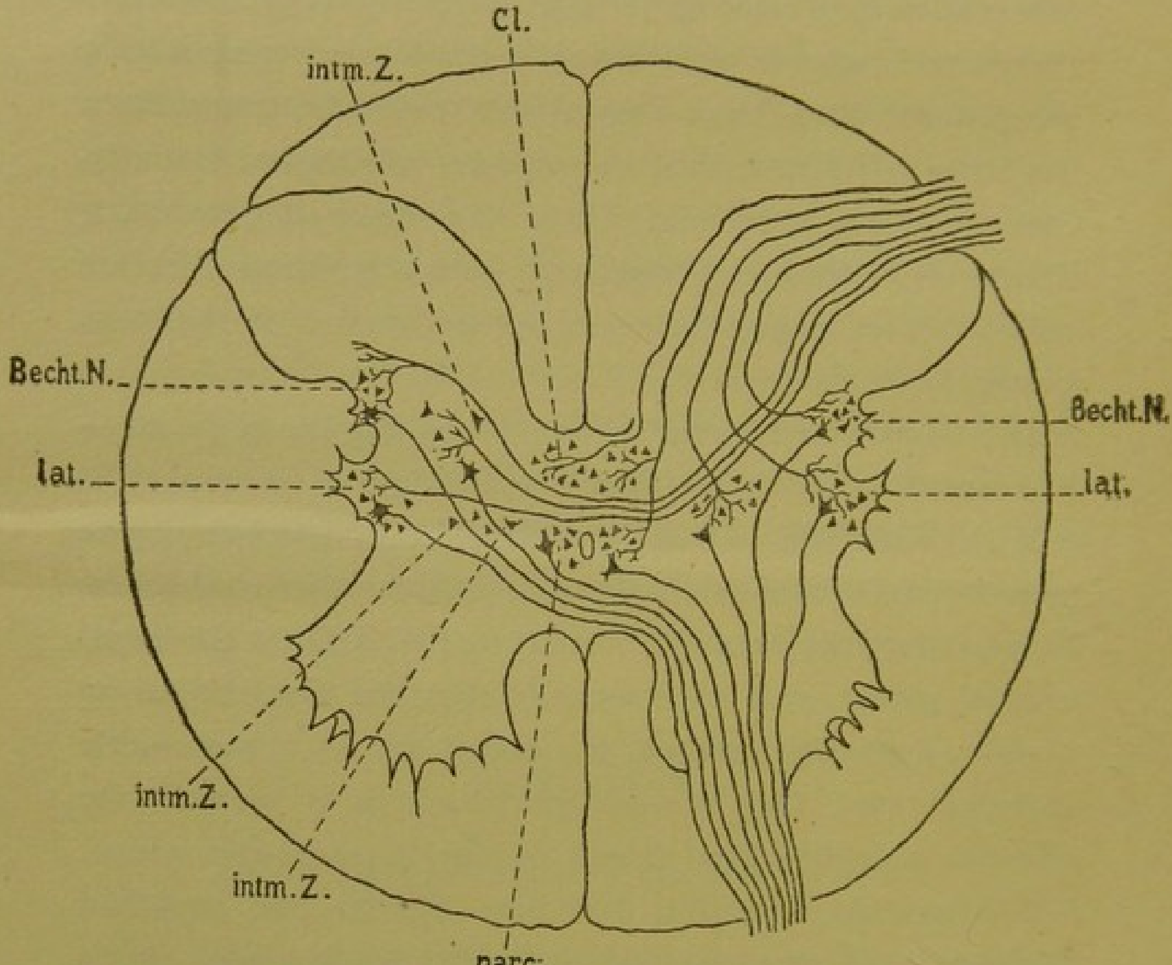
SPINAL LOCALIZATION OF THE SYMPATHETIC.

We have now to approach the question, Which of the altered cell groups are sensory or afferent and which of them motor or efferent in function (see Text-Figure 7).

(1).—*Clarke's Column* (Text-Figure 7, Cl.)—The observation made by Ramon y Cajal that the cells of Clarke's column send their axis cylinders into the direct cerebellar tract, taken in connection with the fact that the latter tract, when severed, degenerates in ascending direction, and with the fact that the collaterals of the ascending and descending branches of posterior root fibres terminate around the cells of Clarke's column, clearly proves the afferent function of this cell column.

Since on the other hand the cells of Clarke's column underwent a more or less extensive atrophy in all our experiments on the sympathetic nerve, that is with the reservation expressed in the foot-note on p. 125; since furthermore in case of extirpation of the lumbar sympathetic ganglia the fibres thus degenerated could be traced from the zone radiculaire into the column of Clarke, two conclusions are permissible: First, that these degenerating fibres are afferent fibres, and secondly, that Clarke's column is an important terminal station for the afferent sympathetic fibres.

(2).—*The Paracentral Group* (Text-Figure 7, parc.)—The question as to the nature of this group is more difficult to establish. If after extirpation of ganglia of the sympathetic chain the method of Marchi had enabled us to trace degeneration of anterior root fibres into the paracentral group or if such a connection had been traced by Gudden's atrophy method, we might say with reasonable certainty that the paracentral group is a nucleus for efferent cerebro-spinal fibres of the sympathetic nerve. Unfortunately, however, both the Marchi and modified Gudden methods proved negative in this respect. It is true that in the case of extirpation of lumbar sympathetic ganglia an area of degeneration was seen ventrad of Clarke's column, near the position of the paracentral group, but this degeneration could not be traced into the anterior root, and in the case of removal of thoracic ganglia of the sympathetic in which a modified Gudden method was used, whatever atrophy of fibres may have been present, could not be detected, as it was masked by the surrounding normal fibres. We can therefore only assert positively the connection of this cell group with the sympathetic nerve by reason of its partial atrophy after removal of sympathetic ganglia. The view that it is a nucleus of efferent function can be accepted only as a hypothesis, which, however, has much in its favor.



TEXT-FIGURE 7.—Diagram illustrating the spinal representation or localization of the sympathetic nerve as made very probable from the degenerations following lesions of the sympathetic chain.

Cl. = Clarke's column.
intm. Z. = Intermediate zone.
Becht. N. = Bechterew's nucleus.
lat. = Lateral horn group.
parc. = Paracentral group.

(3).—*The Lateral Horn Group* (Text-Figure 7, lat.)—The cells of this group bear so much resemblance to those of the paracentral group that, assuming efferent function for the latter, we feel much inclined to attribute the same to the former. This view also can not be proven positively but must for the present remain a hypothesis. In the cat in which the lumbar sympathetic ganglia had been removed, degenerating fibre tracts could be seen passing from the area ventrad of Clarke's column towards the lateral horn, but the fibres could not be traced into the anterior roots, and it is just as likely or even more likely, that they were the continuations of degenerating fibres of the posterior roots. The latter fact would of course not disprove their centrifugal function since Lenhossek's observation has proven the presence in the posterior roots of efferent fibres originating from spinal cord cells, yet nothing positive can be asserted in this respect.

(4).—*Cells of the Intermediate Zone* (Text-Figure 7, intm. Z.)—Many of the large cells of this zone convey the impression of being strayed cells of Clarke's column, and their apparent atrophy in Case No. 415 (see pp. 138–143), would suggest that they bear the same relation to the afferent visceral nerve fibres as the cells of Clarke's column. The small cells of the intermediate zone, many of which were also apparently atrophied in the same case, may have efferent function.

We shall consider the possible specific function of one or the other of these several spinal sympathetic centres in the next chapter.

Chapter XXII.

CONCLUDING REMARKS ON THE LOCALIZATION OF THE SYMPATHETIC NERVE IN THE SPINAL CORD.

After examining our results as obtained by the experimental method of producing degeneration on the one hand, and those which we gained by the study of the anatomical relationships of certain fibre tracts on the other, we may venture the following conception of the anatomical and physiological relations of the "vegetative nervous system" in its relation to the spinal cord.

The different afferent fibres which convey the sensory impulse arising in the vegetative organs to the spinal cord, originate in part at least, from the ganglia or plexuses of the sympathetic system. The most important terminal station for these fibres in the spinal cord is Clarke's columns. These columns are reached by way of the posterior roots. The afferent visceral ("vegetative") fibres contained in one posterior root distribute themselves to both columns of Clarke, terminating upon or around its large cells (Text-Figure 7, Cl.) These cells, on the other hand, send their axis cylinders into the direct cerebellar tracts in which they continue as vertical fibres of the latter. They conduct sensory impulses received from the vegetative organs to the cerebellum. It seems quite likely that many of the large cells of the intermediate zone bear the same relation to afferent sympathetic fibres and to the cerebellum as the large cells of Clarke's column do (Text-Figure 7, intm. Z.) The marked variation in the constitution of the intermediate zone at various levels of the spinal cord has been pointed out on p. 148.

The spinal centres, from which the efferent cerebrospinal fibres of the sympathetic originate, are probably represented in the paracentral group (Text-Figure 7, parc.), in the group of the lateral horn (Text-Figure 7, lat.) and in many of the small cells of the intermediate zone (Text-Figure 7, intm. Z.) The representation is bilateral.

Clarke's column and the paracentral group usually appear as two separate formations in the adult cat. In the young cat they are frequently amalgamated, thus constituting one cell group (compare Plate IV, Figure 7, with Plate IV, Figure 8). We believe that even in the adult the separation is not quite complete. The belief grows upon us that many of the small cells of the vesicular groups are elements belonging in function to the paracentral group. On the other hand, large cells of the type of cells of Clarke's columns are at times found in the paracentral group. Mott likewise assumes that part at least of the cells of Clarke's columns probably give origin to efferent "visceral fibres of the anterior roots." In man the paracentral group seems to form part of Clarke's column except in the upper dorsal and middle sacral region, in which one of us (Onuf) found a cell group which seems to correspond to the paracentral group of the cat, although more laterally situated.

In view of the fact that the spinal centres of efferent fibres of the sympathetic nerve can be excited reflexly from sensory fibres of the vegetative nervous system a connection serving as a reflex pathway for the enactment of visceral, vasomotor or secretory reflexes must be postulated between these afferent "vegetative" fibres and the spinal centres of the efferent "visceral" or vegetative fibres. Such a connection we have striven to demonstrate for the paracentral group by showing the intimate fibre connections between Clarke's column and the paracentral field in Pal specimens (pp. 148–150) and also by the findings of Case 411 (pp. 120–123, and Plate II, Figures 3 and 4). In this case the fibre degeneration in the posterior roots, produced by the removal of lumbar sympathetic ganglia could be traced to an area ventrad of Clarke's column suggesting a termination of these fibres on or around the cells of the adjoining paracentral group. Furthermore, the degenerating tracts seen passing from ventrad of Clarke's column towards the lateral horn (Plate II, Figure 3) suggested a similar reflex pathway to the lateral horn group, provided that these degenerating tracts were the continuations of the degenerating bundles in the posterior roots, which seemed very probable.

As to the rôle of Clarke's column we do not mean to imply that only sensory impressions from the vegetative organs are conveyed to this cell group; on the contrary, we think it quite possible that the sensory impressions from muscles, tendons and joints, for instance, are conducted to it and that part of the fibres which we saw emerge as vertical bundles from Clarke's columns and bend dorso-ventrad may represent "reflex fibres" or "reflex collaterals" which are instrumental in the enactment of deep reflexes (tendon, bone, etc.) Among the sensations which in their totality give us the sense of equilibrium, visceral sensations we think play an important part. It is therefore permissible to assume with Mott that the sensory pathways connected with Clarke's columns conduct not only visceral sensation but also the other sensations which are instrumental in the maintenance of equilibrium, namely, muscular sense, joint sense and the like.

A few words must be said in reconciliation of the contradictory views of some authors, especially Kölliker and Dogiel, regarding the origin and nature of the sensory or afferent nerve fibres found in the sympathetic nervous system.

Dogiel found that the nervous process (axis cylinder process) of certain cells of sympathetic ganglia terminates in a spinal ganglion around cells of a special type, establishing thus the existence of sensory sympathetic nerve elements (compare Text-Figure 4). Kölliker, on the other hand, claims that there are no specific sympathetic sensory fibres but that the visceral sensory fibres are the peripheral branches of the T dividing fibres of the spinal ganglion cells. We have shown that apparently both views are incorrect if adhered to exclusively.

A reconciliation of these contradictory observations can be made if the view is taken that the sympathetic sensory fibre, a fibre which originates from a cell of the sympathetic ganglia or plexuses, ends in Clarke's columns, but that during its passage through the spinal ganglion it gives off collaterals which spin around the cells of the ganglion. Such a "collateral" connection with the typical sensory neuron would enable us to localize visceral sensory impressions *ad superficiem*. We shall say, for instance, that the sensory fibres of the bladder are "collaterally" connected with those sensory neurons whose peripheral branches are distributed in the skin over the region of the bladder. Irritation of the sensory bladder nerves will therefore co-excite the neurons for the skin over the bladder and thus enable us to localize the visceral sensation from the co-existent cutaneous sensation.

And indeed we can localize visceral sensations more accurately *ad superficiem* than as to their depth. It is easier for us to say to what region of the surface of the body the "inner" pain corresponds than at what depth it is. There is no reason, however, to reject the view that part of the visceral sensory fibres are the peripheral branches of the typical peripheral sensory neurons which have their cells of origin in the spinal ganglia, as Kölliker assumes.

Of the specific rôle of the groups which we believe to be endowed with efferent functions we have little to say. We offer as a suggestion only, that the paracentral group of the lower cervical and upper dorsal region may give origin to the pupil dilating fibres of the cervical sympathetic nerve. We found this group especially well developed in the above mentioned region.

In offering the above suggestion we recall the fact that a dilatator pupillæ muscle has never been demonstrated, and that the pupil dilating effect which the cervical sympathetic exhibits, may be due chiefly to the vascular functions of this nerve. If this is so the dilatator pupillæ centre could be considered as part of a general vascular centre, extending through various levels of the cord, which in the middle sacral region may give origin to the nervi erigentes.

Some of the clinical applications to be made from our researches are the following: When retention of urine occurs in tabes, for instance, the sensory bladder fibres are affected, and the pathological changes must be sought in the posterior root fibres passing to Clarke's columns. Cases of syringomyelia that are attended chiefly by vasomotor or trophic disturbances (or disturbances of the vegetative functions of some other kind) are dependent upon a morbid process around the central canal, in the "lateral horn" or in the zone between these two. The region about the central canal should be carefully studied in every case of hemorrhage into the spinal cord, because the blood in dilating the central canal affects first this cell group which we have designated "paracentral," although in man, as we have mentioned, the paracentral groups on most of the levels seem to be amalgamated with Clarke's column. Of the visceral crises those referable to the alimentary canal, such as diarrhœa and vomiting are probably of peripheral origin, although other crises such as those referable to the bladder may be and often are of central (spinal) origin.

From what has been said it is readily apparent that disturbances of the vegetative system should occur least frequently with lesion of the gray matter of the midcervical and lower lumbar cord, unless the lesion affects the gray substance simultaneously with the white substance, in which case it is of course different.

CHAPTER XXIII.

CEPHALIC LOCALIZATION OF THE SYMPATHETIC SYSTEM.

Our contribution to the localization of the sympathetic system in the brain is based upon a study of three oblongatæ which were cut in a series of continuous transverse sections.

1.—*Oblongata of a cat* (*Case No. 414 of the Institute*—see p. 144 *et seq.*) *in which the left stellate ganglion had been extirpated. Hardening in Müller's fluid; cut in transverse blocks; stained in toto with carmine. Nearly every section preserved, and part of them counterstained according to the method of Pal.*

2.—*Oblongata of a cat* (*Case No. 416 of the Institute*—see p. 144 *et seq.*) *in which the right stellate ganglion had been extirpated. Hardening in alcohol. Preservation and staining by the method of Nissl of every second section and in more proximal levels of every third or fifth section.*

3.—*Oblongata of a non-operated healthy cat* (*Case No. 407 of the Institute*). *Hardening in alcohol, staining by Nissl's method. Preservation of every fifth section.*

The oblongata sections which were stained with carmine and according to Pal (Case No. 414), underwent some shrinkage in going through the process of paraffine embedding, and were therefore not very favorable for study. However, we were able to confirm the observations made in the other operated cat and to get information on some points concerning which satisfactory conclusions could not be drawn from study of the other series. In the main, however, our conclusions corroborate the findings in sections of the oblongatæ stained by Nissl's technique.

Observations on some Structures in the Floor of the Fourth Ventricle in the Cat and in Man.—While making our report of the conditions in the operated animals, it seems to us advisable to interpolate some remarks regarding the normal architecture of the oblongata, especially of those parts which lie beneath the floor of the fourth ventricle. This region has taken on renewed interest since the researches of Reinhold, who, on the ground of clinical evidence supported by histological post-mortem examination, concludes that the parts located beneath the ependyma of the fossa rhomboidea are the seat of important vasomotor centres.

Reinhold's study was made on specimens hardened in Müller's fluid, and on some Golgi specimens. We are able to add a description of the conditions as they can be recognized on Nissl's specimens and wish to contribute to a study on some points to which Reinhold has not called attention. We shall now describe the formations found normally beneath the dorsal surface of the oblongata of the cat and at the same time enumerate the areas which were found altered in this region in the animals which had suffered extirpation of one stellate ganglion.

The Nucleus Marginalis Fossæ Rhomboideæ (N. marg. Plate IX, Figures 19–24).—On examining cross-sections of the cat's oblongata at a level of the distal part of the fossa rhomboidea we find, dorsad of the dorsal vago-glosso-pharyngeal nucleus and directly beneath the dorsal surface of the oblongata a nucleus which is especially conspicuous in the region of the calamus scriptorius. Here it forms a sort of mesial projection of the lateral wall of the fourth ventricle. In its cephalic levels it lies beneath the ependyma, just at the lateral extremity of this membrane, where the choroid is attached. (Plate IX, Figure 21). The cellular constituents of this nucleus are small and may for the most part be classed under the type which Nissl has proposed to call karyochrome cells, or nucleus cells* in which the nucleus stains distinctly and is most conspicuous, while the protoplasm of the cell body is present in very small quantity. In over differentiated sections the nucleus seems indeed to form the whole cell, but in more deeply stained specimens one discovers that the cells have richly ramified protoplasmic processes, with triangular shaped thickenings at the point of ramification. An illustration of this is given in Plate IX, Figure 23. The cells are quite densely arranged, and it is this arrangement, together with the rich lacework formed by the protoplasmic processes that gives the nucleus a characteristic appearance in the Nissl specimens. (See also Plate IX, Figure 24, N. marg.)

The position of the nucleus will be best understood if we follow its course caudad where the central canal, though still present, is just opening, undergoing transformation into the fossa rhomboidalis. Here the nucleus occupies the ridge separating the central canal from the dorsal surface of the oblongata. (Plate IX, Figure 19). When the central canal opens this ridge splits in two,

* Nissl distinguishes cytochrome cells or granule, and karyochrome cells or nucleus cells. In the cytochrome cells the substance forming the cell body is very scarce, and the stained nucleus reaches the size of ordinary leucocytes. In the karyochrome cells or nucleus cells (that is, in the type represented in Plate IX, Figure 23) the substance forming the cell body is also very scarce and the nucleus has the size of the nerve cell nuclei. It is in each case larger than the nuclei of the glia cells.

forming on each side a mesad projection of the lateral walls of the fourth ventricle, containing the nucleus. (Plate IX, Figure 20.) The tela chorioidea inferior ventriculi quarti attaches itself directly to the lateral part of the ridge containing the nucleus described. (Plate IX, Figure 21.)

This attachment of the tela chorioidea determines the position of the nucleus in its entire course, except at the lowermost extremity. The further we proceed proximad the more we find the attachment of the tela chorioidea pushed laterad, and with it the nucleus, which always borders the lateral end of the ependyma. *Because of its position it is appropriate to call it the marginal nucleus of the fossa rhomboidea.* (*Randkern der Rautengrube*). Plate IX, Figures 19, 20, 21 and 24, show the position of the nucleus (N. marg.) at the various levels in the cat. Figure 22 of the same plate shows its position in man. As has been mentioned, the nucleus reaches its highest development in the region of the calamus scriptorius and then gradually becomes smaller in its proximal course. At levels in which the hypoglossal and vago-glosso-pharyngeal nuclei have disappeared, the marginal nucleus of the fossa rhomboidea is also apparently gone. We must add, however, that this nucleus does not form a strictly circumscribed mass, as do other nuclei; it gradually loses itself in the environment, sending offshoots in various directions. Indeed, we find a continuation of the nucleus spreading itself in a thin layer beneath the entire surface of the ependyma of the fossa rhomboidea, and from this layer a more pronounced triangular offshoot wedges itself between the dorsal border of the vagus and hypoglossal nuclei. In the subependymal region, however, the cellular constitution is not quite the same, although very similar. Here we find a predominance of very small, long drawn out, slender nerve cells, in which the chromatic structure is scarcely rendered and in which a nucleus can not be definitely distinguished. But aside from these slender elements we find a goodly number of cells of the karyochrome type. Moreover, there is the same rich lacework of processes that we found in the main nucleus.

In studying the series still further proximad we find that in certain places the main nucleus reappears. It seems in a certain degree to keep pace with the manner of attachment of the tela chorioidea. Where this attachment is broader, as, for instance, at the level of the tuberculum acusticum, the main nucleus becomes again more prominent. The subependymal division of the nucleus is more prominently developed in the region of the facial knee and abducens nucleus. It forms a broad layer here, and projects a rather large wedge into the region laterad of the facial knee. Mesad of the facial knee another, but smaller wedge, penetrates ventrad.

In man the nucleus marginalis fossæ rhomboidea is also distinctly present. A comparison of Figures 20 and 21, of Plate IX, which show the nucleus in the cat, with Figure 22, (same plate) representing it in man, shows the similarity of the nucleus in both instances. In man, as in the cat, it borders the lateral edge of the ependyma lying directly beneath the dorsal surface of the oblongata, but somewhat more laterad of the vago-glossopharyngeal nucleus than in the cat. Plate IX, Figure 24, *marg.* shows the nucleus under higher power as it appears in the cat.

The cellular elements of this nucleus seem also to be the same in both man and the cat. Unfortunately, the specimen from the human oblongata from which we made the sections underwent some shrinkage during the process of paraffine embedding. Therefore the Nissl sections made from this specimen do not show the finer structure as distinctly as the sections from the normal cat. Yet the general character of the cells seems to be essentially the same as we described it for the cat.

Reinhold makes no mention of the nucleus marginalis fossæ rhomboideæ, but he has given an exact description of the subependymal region, which he considers to play the part of a vasomotor centre. In three cases of marked vasomotor disturbances he found numerous hemorrhages in the region which we have called the subependymal division of the nucleus marginalis fossæ rhomboideæ, and in these cases the hemorrhages were undoubtedly the cause of the vasomotor disturbances. The similarity of the structure of the subependymal region with that of the nucleus marginalis fossæ rhomboideæ makes it highly probable that this nucleus constitutes part of the vasomotor centre as described by Reinhold. We may remark here that this nucleus was quite normal in our operated animals.*

The Nucleus of the Medullary Layer of the Hypoglossus (Plate IX, Figure 24, *N. med.*)—Aside from the nucleus marginalis fossæ rhomboideæ and its subependymal division, we find in the cat a well developed and clearly out-

*The possibility that the cells seen by us in the nucleus marginalis fossæ rhomboideæ and in its subependymary division are neuroglia cells and not nerve cells, was seriously considered ; but although it may be rather difficult to decide as to the specific nature of these cells on the basis of histological examination of Nissl specimens alone, yet the following facts speak in favor of the nervous character of part at least of these elements. Many of the cells have a distinct single nucleolus and dichotomically ramified processes. Moreover, Reinhold, by means of Golgi s method found nerve cells in the region designated by us as the subependymal division of the nucleus marginalis fossæ rhomboideæ and, finally, he produced clinical evidence pointing to the existence of a vasomotor centre located in that region.

lined *cell group which occupies the space between the vagus and hypoglossal nuclei, lying thus within the so-called medullary layer of the hypoglossal nucleus* (Marklager des Hypoglossus), and may therefore very properly be designated the *nucleus of the medullary layer of the hypoglossal nucleus* (see Plate IX, Figure 24, *N. med.*); at least we shall for the present maintain this neutral designation. Dorsad this nucleus joins directly the triangular wedge by means of which the subependymal division of the nucleus marginalis fossæ rhomboideæ projects between the dorsal borders of the hypoglossal and vagus nuclei. Caudad the nucleus can be traced almost to the region in which the central canal opens into the fossa rhomboidea. In cephalad direction it begins to lose its individuality in the region in which the hypoglossal nucleus begins to disappear; there it gradually blends with and loses its identity in a cell group which seems identical with the nucleus funiculi teretis. Its most marked development is in the proximal half of the hypoglossal and dorsal vagus nuclei. In its distal part this nucleus is composed mostly of small cells with relatively large nuclei and small ovoid cell bodies, the cell substance of which does not show a well marked chromophile structure. Aside from these elements we find somewhat larger cells which are distinctly multipolar and show such an arrangement of the chromophile substance as we find in the cells of motor nerve nuclei. The further proximad we proceed the more do the elements last described predominate in number. In the region in which the hypoglossal nucleus disappears these larger elements constitute the main part of the cell group described. At the same time the latter has moved more mesad, assuming the position in man in which the nucleus funiculi teretis is situated. Whether the two nuclei together, namely, the nucleus funiculi teretis and that of the medullary layer of the hypoglossal nerve ought to be considered as one nucleus, we do not venture to assert; nevertheless we think this not improbable. We must not forget, however, that at the level of the hypoglossal nucleus the nucleus funiculi teretis in man always maintains its position mesad of the latter, while the nucleus of the medullary layer of the hypoglossus in the cat is situated between the hypoglossal and dorsal vagus nuclei. Its position, therefore, is not identical with that of the nucleus funiculi teretis. In studying Figure 239, Edinger's text-book, one gets the impression that what we have called the nucleus of the medullary layer of the hypoglossal nucleus is identical with the nucleus accessorii represented in this figure, but if this is a nucleus of the accessory, we should judge from the smallness of the cells that it gives rise, not to somatic but to visceral efferent fibres of this nerve. Obersteiner does not represent the nucleus described, in his drawings, but (on p. 431 of the 3d German edition of his text-book), quotes Staderini as the discoverer of a nucleus, called by him nucleus intercalatus, which apparently is identical with our nucleus of the medullary layer of the hypoglossus nucleus. We should not have taken the pains to describe this nucleus with such detail had not the quotation above referred to escaped notice on our first perusing Obersteiner's data on this subject.

In examining our series (Case 416) we were inclined to believe at first that the area of the nucleus of the medullary layer of the hypoglossal was somewhat smaller on the left side (opposite the side of extirpation) than on the right; but repeated examination convinced us that this was the result of some local shrinkage in the specimen. The cellular constitutents were not changed. It seemed, on the contrary, as if the nucleus on the left side contained a greater number of larger elements than that of the right. This must be accounted for, in all probability, by some asymmetry dependent upon an inclination of the plane of section towards one side. At any rate, our final conclusion is that the nucleus of the medullary layer of the hypoglossal is normal on both sides.

The Nucleus homologous of Clarke's Column.—At the levels of the bulbar division of the hypoglossal and dorsal vagus nuclei we meet (in the cat) with another cell group (Plate IX, Figure 24, *N. homol. Cl.*) which is situated at the ventral and lateral, mostly at the ventral, borders of the so-called solitary bundle * (respiratory bundle, descending root of the IX and X). The cells of this group are predominantly large, multipolar, and may be classified on the whole, from their chromatic structure, among the stichochrome cells (Nissl).† This cell group is very constant, but segmented, disappearing in a few sections, and reappearing in the next. In the spinal division of the dorsal vagus nucleus it is also present and well developed, perhaps even more developed, but it often becomes mixed up with the adjoining part of the nucleus of the posterior columns. Further caudad it is rather well defined at the lower levels of the pyramidal decussation, but especially caudad of it; that is, at the most proximal levels of the cervical portion of the cord. Proximad it becomes again

* We do not mean the gelatinous substance acompanying the solitary bundle but an individual nucleus distinctly separated from this substantia gelatinosa nucleus.

†By stichochrome cells Nissl understands that type of cell in which the chromophile part of the cell body is arranged in the form of equally directed stripes.

a well defined circumscribed group at the level at which the central canal opens into the fossa rhomboidea. From this level proximad it can be traced a distance of one and one-half mm. in axial (cephalo-caudad) direction. This gives an idea of the relative strength of its bulbar division, if we add that the dorsal vagus nucleus (in the cat) extends axially through a distance of about 2.2 mm.* in its bulbar division. In the oblongata of the cat registered as Case No. 416, in which we extirpated the right stellate ganglion, (Nissl series) this nucleus appeared normal on both sides; but in the cat registered as Case No. 414, in which the left stellate ganglion had been extirpated (carmine and Pal series), the nucleus of the left side showed a distinct reduction in the number of cells as compared with the right side.† *From reasons which we shall explain later, we are inclined to consider this group as the homologue of Clarke's column in the oblongata* (Plate IX, Figure 24, *N. homol. Cl.*).

The Vagus Nuclei.—It remains for us to describe the condition of the nuclei connected with the vagus nerve. These are the nuclei in which we expected particularly to find changes, since the vagus nerve gives off a large communicating branch to the stellate ganglion. On the other hand, owing to the distance of the lesion from the central origin of the nerve, and owing to the fact that the lesion was not produced in newborn cats, but in those which had reached the age of two months and six weeks, respectively, we could

*In order to be able to measure distances in longitudinal (axial) direction, the thickness of each section was recorded on each slide.

† We admit, however, that no count of cells was made, and it might not have been quite convincing if it had been made, since after all, the series was interrupted in some places, so that our conclusion is based more on a general impression.

not expect any marked ascending changes in the efferent fibres of the pneumogastric nerve nor in the cells from which they originate in the oblongata. We should expect still less marked changes in the intrabulbar course of the afferent or sensory fibres. For these are said to originate for the most part from cells of the ganglion jugulare vagi in a manner analogous to that by which the sensory fibres of the posterior roots of spinal nerves originate from cells of the spinal ganglia. Consequently, if this view is correct, the lesion, which was peripherad of the ganglion vagi, affected only the peripheral branch of the T branching fibres of these cells, and not, or only indirectly, its central branch. We were prepared, therefore, to find very slight if any central changes.

The central nerve nuclei with which the vagus is said to be connected are the dorsal vagus nucleus called also the vago-glassopharyngeal or small-celled vagus nucleus (Plate IX, Figure 24 *N. X.*) which is situated in its bulbar division laterad of the hypoglossal nucleus beneath the floor of the fourth ventricle; second, the nucleus ambiguus; third, the substantia gelatinosa of the solitary bundle (respiratory bundle, descending root of the lateral mixed system, etc., Plate IX, Figure 24, *sol.*)

Histological Examination of the Vagus Nuclei in the Experimental Cases.—In the two cats in which the stellate ganglion had been extirpated, the nuclei mentioned in the preceding paragraph showed the following conditions:

I.—*Dorsal Vagus Nucleus* (called also vago-glossopharyngeal nucleus or small-celled vagus nucleus, see Plate IX, Figure 24, *N. X.*)—In the series stained by Nissl's method (Cat 416—right stellate ganglion extirpated) the spinal division of the nucleus of the right side shows a slight but constant reduction of the size of the cells on comparison with the left side. But the cells of the right side are likewise distinctly smaller than the cells of the same region in the normal series. Otherwise, no striking alteration of structure is noticed in the cells, either on the right or on the left side. In the bulbar division the vagus nucleus appeared normal on both sides. The cells are as full and large as in the normal series. In some sections it appeared as if the area of the nucleus of the left side was smaller than on the right (operated) side, but this could be shown to be due to some local shrinkage, and the cells themselves showed no constitutional difference from those of the right side.

II.—*Nucleus Ambiguus.*—It is somewhat difficult to identify this nucleus in the cat. The conditions present seem to us to be the following:

At the level wherein the pyramidal tracts have just crossed (if we proceed proximad in the series) a nucleus of good size and with large cells, bearing on the whole a great resemblance to the facial nucleus, makes its appearance. It is situated at first close to the lateral border of the oblongata, midway between the substantia gelatinosa Rolando and the pyramidal tracts. Its presence causes a considerable bulging of the oblongata in this region. In following the nucleus proximad, we see it become larger, soon to reach its greatest development. At the level at which the inferior olivary bodies are most conspicuous, the nucleus has moved dorso-mesad, assuming a position latero-dorsad of the olivary body, on which it borders directly. It splits up at the same time into sub-groups, and thus forms a picture very similar to that of the facial nucleus. In this region it has quite a similar position to that which the facial nucleus had in higher levels. From the position and arrangement of the nucleus described, we believe it to be identical with the nucleus ambiguus. However this may be, the nucleus described is absolutely normal in our specimens, and also all the scattered large nerve cells in the gray reticular formation appear normal. In short, we could not find any changes in the region which in position corresponds to the nucleus ambiguus.

III.—*Solitary Bundle, with its Gelatinous Substance* (Plate IX, Figure 24, sol.)—The Nissl specimens do not permit us to draw definite conclusions regarding the condition of this formation. In the carmine series the area, both of the bundle and of the gelatinous substance is somewhat smaller on the left (operated side) than on the right.

In completing the report of our findings, we wish to state that a careful examination of the nuclei of the posterior column, of Deiter's nucleus, of the nucleus of the lateral column, of the nucleus of the anterior column (Obersteiner), (nucleus respiratorius, Mislawski), of the nucleus centralis inferior (Roller), and the hypoglossal nucleus shows that these were normal on both sides.

Chapter XXIV.

CONCLUDING REMARKS ON THE LOCALIZATION OF THE SYMPATHETIC SYSTEM IN THE BRAIN.

We shall now endeavor to state the conclusions that we feel warranted in drawing from the facts and observations so far presented regarding the anatomical relation of the sympathetic to the brain of the cat. It has been shown that extirpation of one stellate ganglion is followed within three months by bilateral atrophy of the spinal division of the so-called vago-glossopharyngeal nucleus (Text-Figure 8, p. 182, N.X. dors.; also Plate IX, Figure 24, N.X.) Although the atrophy is very slight, and predominantly on the side corresponding to the operation, there can be no doubt as to the reality of its occurrence.* The nucleus ambiguus, so far as our observations go, has remained intact after such extirpation. It will profit us to dwell upon these two facts and to attempt their proper interpretation.

In the operation above mentioned only those fibres of the vagus which are connected with the stellate ganglion were injured. It therefore seems legitimate to conclude that no somatic† but only visceral fibres were implicated in the lesion. We found the vago-glossopharyngeal nucleus altered and the nucleus ambiguus intact. If it be assumed therefore that the vago-glossopharyngeal nucleus has motor functions, it is safe to conclude that it is this nucleus, and not the nucleus ambiguus which gives origin to the visceral, or splanchnic, efferent fibres. Van Gehuchten, Kölliker and His do not admit that this nucleus has motor functions and in support of their contention they set forth the fact that fibres of the vagus have been seen terminating in this nucleus. We desire to say in the first place that this can not be offered in evidence to negative the claim that the nucleus has motor function. Let us assume for the present that the fibres of the sensory root terminating in this nucleus are collaterals

* In revising the proofs we feel that the assertion that there can be *no doubt* of the bilateral atrophy of the spinal division of the vago-glossopharyngeal nucleus may have been put a little too strongly, too positively. We are aware that it may be very difficult to judge of slight changes occurring in the size of a nucleus or of its cells, as the possibility of a diminution in size from post-mortem shrinkage of some origin or other must always be kept in view. Moreover, the fact that only every second or third or fifth section of the series was mounted, presented a further complication. A measurement of the cells did not seem promising enough to repay for the great amount of work which it would have required and was therefore omitted. So much more were we glad to find that the result of van Gehuchten's recent researches (Travaux du Laboratoire de Neurologie publiés par A. van Gehuchten, Année 1898, deuxième fascicule, p. 275). clearly proves the correctness of our view of the efferent function of the vago-glossopharyngeal nucleus, since this author, by means of Golgi's method, could trace the axis-cylinder of the cells of the vago-glossopharyngeal nucleus into the root of the X nerve.

† By somatic fibres we mean nerve fibres supplying somatic muscles, *id est*, voluntary striated muscles, such as the muscles moving the head, trunk and extremities.

of the main fibres, and that these collaterals are the ones that subserve the execution of bulbo-visceral reflexes. We have assumed a similar reflex pathway in the spinal cord between afferent vegetative fibres and the cells of the paracentral group. It is conceivable that the conditions in the oblongata are homologous in this respect. We may even venture the opinion that the vago-glosso-pharyngeal nucleus is the homologue of the paracentral group of the cord. Indeed the topography of this nucleus is analogous if we consider its spinal division. The principal difference is, that the paracentral group forms, so to say, a longitudinal chain of round nests on both sides of the central canal; the vagus nucleus, in its spinal division, is on the other hand, drawn or pushed out to a considerable degree in a meso-laterad direction. It should be borne in mind, however, that in this region the neural axis—incident upon the transition from the spinal cord to the oblongata—undergoes considerable morphological changes and transpositions. One of these is that the bridge separating the central canal from the dorsal surface of the cord or oblongata becomes more and more narrow until when the central canal has opened into the fourth ventricle it disappears entirely.* This process of opening we can best represent to ourselves by assuming that through a force acting in wedge-like manner, that part situated dorsad of the central canal becomes split in two and pulled apart, so that that which was originally the median or sagittal plane, dorsad of the central canal, assumes in the fourth ventricle a horizontal position, vertical to the median plane, and that those parts which before the opening into the fourth ventricle lay most dorsad, assume

* With the exception of the tela chorioidea ventriculi quarti, which remains as a covering for the ventricle.

in the fourth ventricle a quite lateral position. This implies also that the longitudinal axis of the posterior horn instead of being placed almost parallel with or at a slight angle to the median plane as is the case in the spinal cord, assumes an almost horizontal direction, vertical to the median plane, at the level of the fourth ventricle. If we consider furthermore that the nuclei of the posterior columns make their appearance here, crowding themselves in at the place which in the spinal cord was the mesial border of the posterior horn, it is easily seen how the posterior horn becomes drawn out in its longitudinal axis and how by this crowding process the vagus nucleus becomes elongated in meso-lateral direction. Not only is there an homology in position between the paracentral group and the vago-glossopharyngeal nucleus but also in structure. The cells of the vago-glossopharyngeal nucleus resemble in size, shape and constitution those of the paracentral group.

If we maintain this homology of the vago-glossopharyngeal nucleus with the paracentral group, an endeavor must be made to extend the conception so as to embrace other relationships. We have assumed for the spinal afferent visceral fibres a double connection. First, with the cells of Clarke's column—cerebellar pathway—and second, with the cells of the paracentral group—spinal reflex pathway. What then is the homologon of Clarke's column in the oblongata? To this we answer: The nucleus which is situated at the ventro-lateral border of the solitary bundle (*N. homol. Cl.* Text-Figure 8, p. 182, and Plate IX, Figure 24) and which in one case of extirpation of the left stellate ganglion showed to all appearance a reduction of the number of cells three months after the operation, although it must be admitted that in another case in which the right stellate ganglion had been extirpated in a young cat five months previously to the death of the animal, the said nucleus was found to be normal. In its spinal portion the solitary bundle is situated at the lateral border of the vago-glossopharyngeal nucleus and slightly dorsad of it. In other words, the nucleus which we believe to be the homologon of Clarke's column occupies a position laterad to the vago-glossopharyngeal nucleus. Clarke's column, on the other hand, is situated dorsad to the paracentral group, but we must not forget that those forces which—as explained on pp. 175 and 176—caused the vago-glossopharyngeal nucleus to extend in a meso-laterad direction, may have crowded laterad the nucleus which we are now considering.

There can be no objection therefore to saying that the vago-glossopharyngeal nucleus preserves a position quite analogous to that occupied by Clarke's column in reference to the paracentral group. Indeed, we were led in the beginning to think of this nucleus as the homologue of Clarke's column chiefly from a consideration of its topography and from its relation to the vago-glossopharyngeal nucleus.

In seeking some confirmation of our supposition regarding this nucleus—as the homologue of Clarke's column—we found on searching the literature that Stilling must have had a very similar idea in mind, nearly half a century ago. In describing the relationships of Clarke's column in the various levels of the cord, he stated that in following this group cerebralwards from the lower dorsal region—in which it is best developed—that the group began to disappear in the upper dorsal region and that when the level of the cervical enlargement was reached, it could scarcely be made out. Yet Stilling knew that it reappeared at the level of exit of the first pair of cervical nerves. Moreover, he showed that at this level it does not have the same position relative to the other components of the cord as in the dorsal region, and very naturally, as the configuration of the cord is different. He pointed out that, at the level of the first pair of cervical nerves, Clarke's column was situated further laterad, midway between the central canal and the lateral border of the gray substance on a plane with the central canal. We can fully confirm this observation, as we have seen this nucleus in the position described by him, at this upper cervical level. For some distance further cephalad it becomes less distinct, owing, in part at least, it is believed, to the obscuration caused by the decussation of the pyramids. Nevertheless it can be traced distinctly into the position ventro-laterad of the solitary bundle, which we have already described. It is true that this cell group was found normal in one of the two cases of extirpation of the stellate ganglion examined, but this does not entirely disprove the conception just outlined, since in some way or other, by collateral nerve supply a recovery of the cells could have taken place, after the occurrence of retrogressive changes. Besides, in the other case of extirpation of the stellate ganglion which we examined, a reduction of the number of cells seemed present in the nucleus in question.

It may seem daring to enter the field with such a conception of the dual afferent and efferent functions of one and the same cell-group, namely, the vago-glossopharyngeal nucleus, and we appreciate the necessity of fortifying our claim and position by furnishing further evidence. Kölliker, conceding that this nucleus is a terminal sensory nucleus, attempted to trace the axis cylinder of its cells into the fillet, but he was unable to do so. He says emphatically that neither in the Golgi sections nor in sections stained according to the Weigert method could he find fibre bundles taking the course of the fillet fibres.

So much to show that it is by no means proven that the cells of the vago-glossopharyngeal nucleus are instrumental in the conduction of centripetal impulses. On the other hand, we must not forget that Forel, from a study of specimens made according to Gudden's method of investigation has always maintained that the vago-glossopharyngeal nucleus is motor in function. According to this investigator, if the nerve be torn out in newborn animals the atrophy that follows is quite indistinguishable from the atrophy that is observed after similar lesions in motor nerve nuclei, and quite unlike the atrophy that occurs in the sensory terminal nuclei of the order of the substantia gelatinosa Rolandi after severance of a peripheral sensory nerve.

It should likewise be mentioned that Gaskell emphasizes the efferent function of the vago-glossopharyngeal nucleus.

According to van Gehuchten, the sensory fibres of the pneumogastric nerve have their cells of origin in the ganglion jugulare and the ganglion nodosum vagi. These cells give off a T branching fibre, one branch of which passes to the periphery, the other, the central branch, entering the oblongata by way of the vago-glossopharyngeal root. When it arrives at the level of the solitary bundle, this central fibre divides into a descending branch which becomes a vertical fibre of the solitary bundle and a horizontal branch which he believes ends in the vago-glossopharyngeal nucleus. This destiny of the fibres fits in with the view that looks upon the horizontal branches as reflex collaterals acting upon motor cells of the vago-glossopharyngeal nucleus, and also with the view which teaches that the latter is a terminal station for sensory fibres. We desire to call attention to another point. On page 469 of Kölliker's Gewebelehre is pictured the solitary bundle as seen in Golgi specimens showing vertical fibres which give off horizontal collateral branches in opposite directions. As we have said, van Gehuchten saw similar horizontal collaterals terminate in the vago-glossopharyngeal nucleus. It may well be assumed that those horizontal collaterals which pass in the opposite direction towards the nucleus considered by us to be the homologue of Clarke's column, terminate in this nucleus. Although this has not been actually demonstrated it seems to us not at all impossible or improbable. We venture, indeed, to believe that we have furnished some facts that are not at all in contradiction but rather in harmony with our conception of the central sympathetic connections and of the efferent functions of the vagus nucleus.*

It seems accordingly to us more appropriate to make a distinction between a nucleus of a motor, somatic, order and a visceral, splanchnic or vegetative nucleus (that is a nucleus that gives origin to somatic† efferent fibres and a nucleus that gives origin to vegetative or visceral efferent fibres) than to make a distinction between a vagus—an accessory—and a glossopharyngeal motor nucleus. In making the distinction proposed we may consider the nucleus ambiguus as the somatic motor nucleus of the so-called lateral mixed system, namely, of the vagus and glossopharyngeal and in part also of the accessory nerves

* Regarding van Gehuchten's recent researches on this nucleus see foot note p. 174.

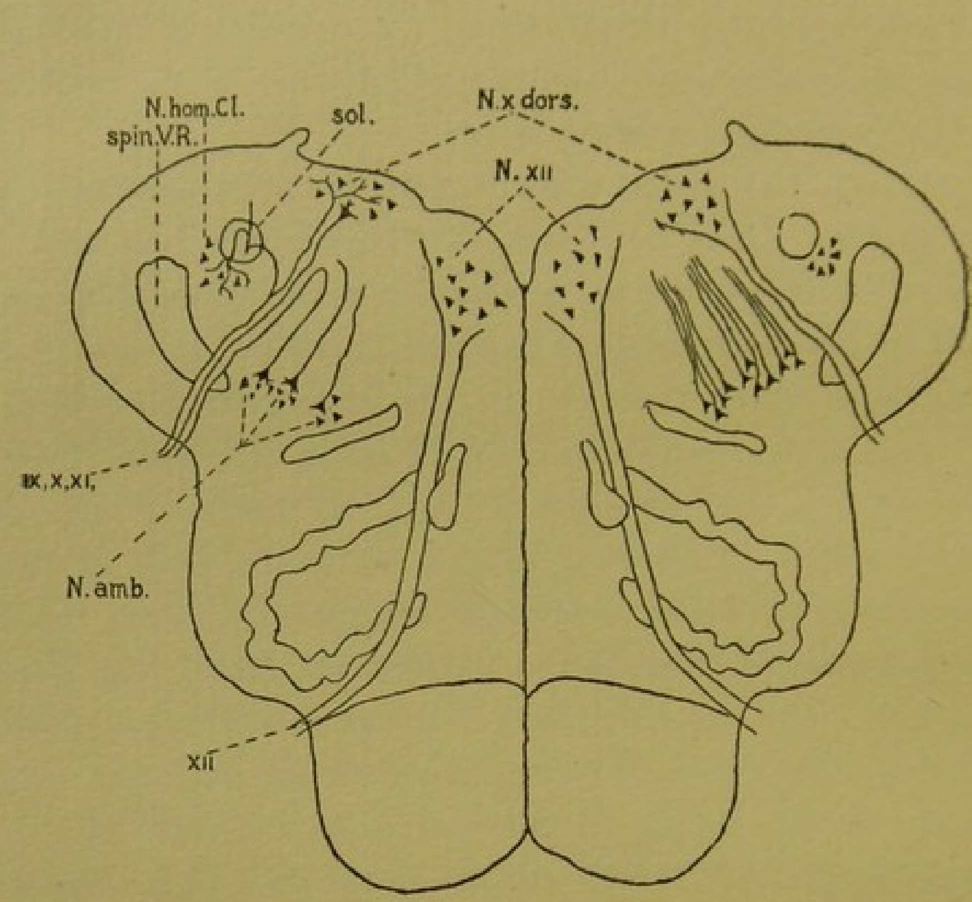
† See second foot note p. 174.

(Text-Figure 8, p. 182, N. amb.) That which is called the vago-glossopharyngeal nucleus would then be the nucleus of the vegetative efferent fibres.

Gaskell who makes a distinction between somatic and splanchnic fibres considers the trigeminus root as the somatic root, and the solitary bundle as the splanchnic root, and we are much inclined to share his view. In this sense the vagus fibres that end in the vago-glossopharyngeal nucleus are the reflex fibres or the reflex collaterals (Text-Figure 8, p. 182, that fibre of IX, X, XI that terminates in *N. X. dors.*) According to this view, the cells of this nucleus give origin to efferent sympathetic fibres, being homologous to those of the paracentral group (see same figure). The afferent visceral fibres of the vagus would have besides these collaterals a connection with the cells of the nucleus which we consider to be the homologue in the oblongata of Clarke's column in the cord (Text-Figure 8, p. 182, *N. homol. Cl.*), thus establishing a connection with the cerebellum.

The nucleus which we described as the nucleus of the medullary layer of the hypoglossal nucleus (called nucleo intercalato by Staderini, and which Edinger pictures as a nucleus of the XI nerve—see Plate IX, Figure 24, N. *med.*) may very well be connected likewise with efferent fibres of the sympathetic system.

Of the gray mass which we have described as the nucleus marginalis fossa rhomboideæ (Plate IX, *N. marg.*) we believe that it has no direct connection with efferent or afferent fibres of the vegetative system. It seems to us much more probable, in view of its similarity and continuity with the subependymal structures which Reinhold has pointed out, that it forms part of the vasomotor centre which he has located in this region.



TEXT FIGURE 8.—Diagram to show the relation of the so-called lateral mixed system of nerves (IX, X, XI root) with the vago-glossopharyngeal nucleus, with the nucleus ambiguus. with the solitary bundle and with a nucleus which we consider to be the homologue of Clarke's column. These relations are suggested among other things by the changes in the oblongata following removal of the stellate ganglion.

N. X. dors.—Dorsal vagus nucleus or vago-glossopharyngeal nucleus, so-called.=nucleus for the visceral or vegetative efferent fibres of the lateral mixed system (IX, X, XI nerves).

IX, X, XI.—Common root of the IX, X, XI nerves (=lateral mixed system).

N. amb.—Nucleus ambiguus=nucleus for the somatic efferent fibres of the lateral mixed system (IX, X, XI nerves).

sol.—Solitary bundle called also trineural fascicle or descending root of the lateral mixed system.

N. homol. Cl.—Nucleus homologue of Clarke's column.

N. XII.—Hypoglossal nucleus.

XII.—Hypoglossal nerve.

spin. V. R.—Spinal trigeminal root.

As to the possible location of the primary centres or terminal stations of efferent or afferent nerves of the vegetative system in other regions of the central axis we have not been able to form sufficiently substantiated conceptions to warrant us in giving definite expression to them. We may however venture the suggestion that the substantia ferruginea and the large vesicle-shaped cells accompanying the cerebral V root are the homologons of the paracentral group and of the vago-glossopharyngeal nucleus. Their position especially lends color to this view. That the function of these cells is motorial has practically been established by the investigations of Ramon y Cajal, van Gehuchten and Lugaro, who were able to trace their neuraxons through the cerebral V root into the motor root of the V nerve. Furthermore, Kljatschkin found that this root degenerated in descending direction. Its motor function being granted, and the homology of position of the cell groups from which it originates with the paracentral group in mind, it seems legitimate to postulate its sympathetic nature.

Chapter XXV.

RECAPITULATION OF THE RESEARCHES.

Although it is difficult to encompass in a few paragraphs the results of our experiments and observations, we shall endeavor to state, for the purpose of easy review, some of the more important conclusions:

I.—*Physiological.*—It was pointed out that the sympathetic nervous system of the cat, although essentially homologous to that of man presents some variations of arrangement. These differences are now well established and we shall not restate them here.

In regard to the influence of the sympathetic upon lachrymal secretion, our results were rather contradictory. Removal of the stellate ganglion in one animal apparently prevented secretion of the lachrymal gland of the operated side when pilocarpine was instilled, while in two other cats it did not have this effect. In one of these two cats, on the contrary, the secretion was more profuse on the operated side. Naturally the lachrymal secretion was an artificial one caused by pilocarpine. We concluded therefore that the results were so contradictory that further experimentation is necessary before positive conclusions can be drawn (page 56).

In reference to the sweat secretion our experiments make it seem very probable that not all sweat secretory fibres of the fore paw pass through the stellate ganglion and through the main trunk of the sympathetic in general as Luchsinger and Langley assume but that a good portion of them follow other pathways, and that these fibres develop a compensatory function so strongly as to entirely mask the loss of function. But yet we had to note the paradoxical fact that in a cat in which the stellate ganglion was removed there was sweating of all the paws except the left fore paw, as the result of the animal's struggles during etherization (pp. 58–62).

In reference to the influence of the sympathetic system on the pupil, our experiments led us to believe that the cervical sympathetic contains not only pupil-dilating fibres but very probably pupil-contracting fibres as well. They showed, furthermore, that the myosis caused by resection of the stellate ganglion, which operation implies severance of the cervical sympathetic nerve, disappears entirely or almost entirely within a few months, proving by this compensation of function that not all pupil-dilating fibres are furnished by the cervical sympathetic nerve (pp. 91–93).

Regarding digestion, we found that disturbance of this function followed invariably, on removal of the stellate ganglion, the lower thoracic portion of the sympathetic, and of a semilunar ganglion. The digestive disturbances that ensue after removal of the stellate ganglion are, however, more marked and more persistent than those noted after removal of the lower thoracic sympathetic. They consisted of diarrhœa and of putrefaction of the fæces. They were more or less remote symptoms and they showed a progressive tendency (see pp. 65–67).

We learned that removal of one stellate ganglion as well as defect of the lower part of the thoracic sympathetic (including the splanchnic at this level) gives rise to attacks of sneezing, to paroxysms of coughing and to hiccough. The cough occurs not only spontaneously, but a paroxysm of coughing could always be precipitated by stroking the animal's back particularly the nuchal portion. Removal of the stellate ganglion causes in addition, first a mucous, then a purulent discharge from the nasal mucous membrane. In one case it produced a chronic purulent bronchial catarrh with lobular infiltration of the lungs. The attacks of cough and hiccough gave the impression of nervous symptoms due to defective inhibitory action. The respiratory disturbances were more grave with removal of the stellate ganglion than with resection of the thoracic sympathetic in its lower portion (pp. 77–81). We noted that resection of the lower part of the thoracic sympathetic was followed by diabetes and considering the large amount of sugar found four months after the operation we are led to the belief that the glycosuria caused by such lesions is not temporary but permanent and seems to have a tendency to increase rather than to diminish (pp. 70–71).

In reference to the effect of extirpation of the stellate ganglion on the local temperature, we found that there was an immediate and a remote increase of from one to two degrees Fahrenheit (p. 74).

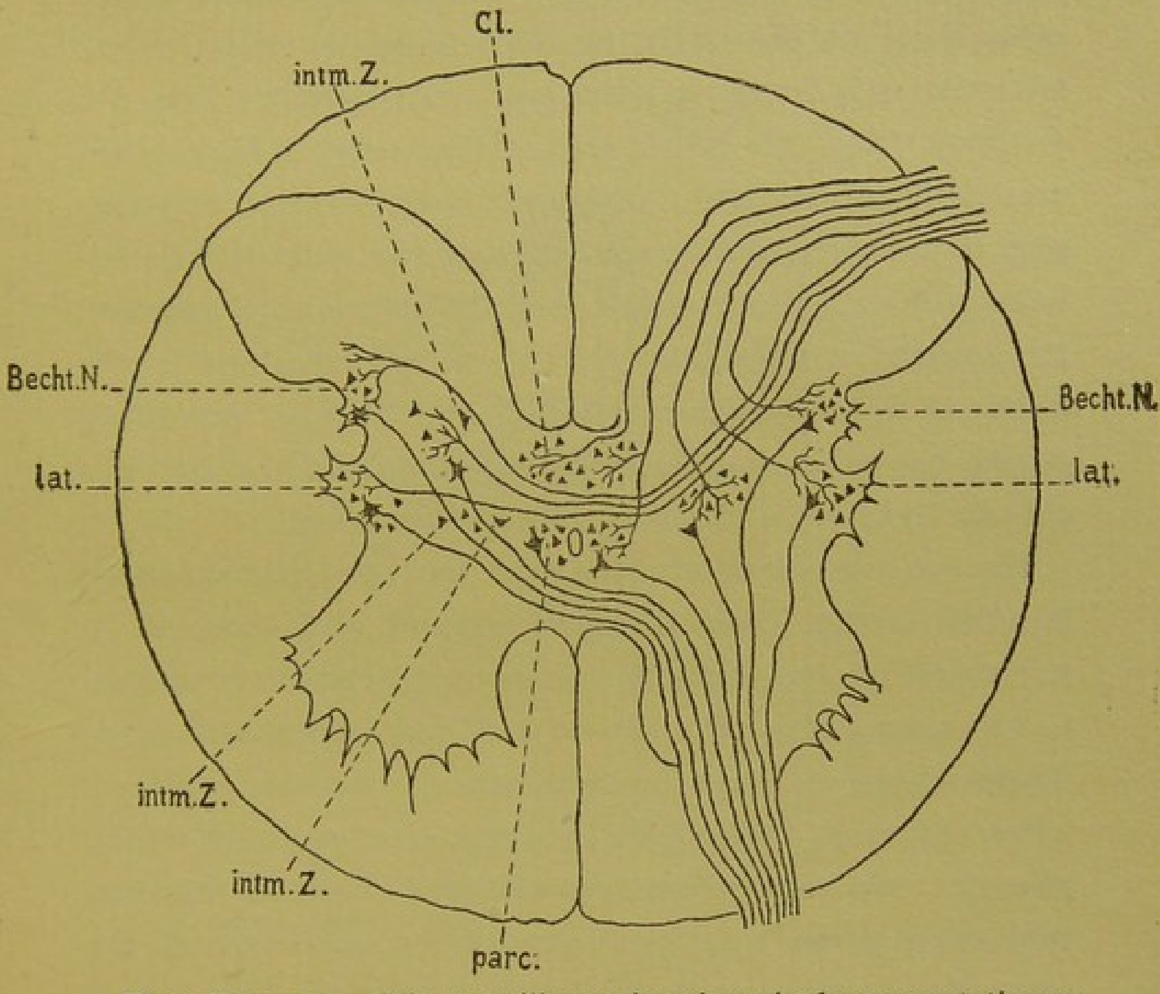
Concerning the pilomotor nerves we concluded that although they have on the whole the segmental distribution which Langley and Sherrington attributes to them, there must be a collateral supply, or a direct cerebrospinal supply which can, in the course of time, entirely replace the functional loss which extirpation of three or four successive ganglia causes (pp. 88–89).

The trophic influences that we observed in connection with lesions of the sympathetic were most evident after removal of the stellate and the lower thoracic ganglia. They were bilateral although quite irregular in distribution and were predominantly cutaneous (partial alopecia) (see pp. 95–96). It is probable that the nasal, bronchial and laryngeal secretion already spoken of may be on a trophic basis.

We emphasized the necessity of considering the immediate and the remote consequences of operation on the sympathetic system. The remote effects may be reparatory, or they may be progressively destructive.

We called attention to a mode of research that may elicit information not obtainable with the usual methods of investigation. This method consists in awaiting the appearance of phenomena of compensation which often instruct us whether a certain set of fibres or a definite nerve or ganglion is concerned exclusively in the performance of a given function, or whether other nerves and ganglia share in the enactment of this function. Illustrations of this are given by us in the observations made on the pupil of a cat in which the stellate ganglion had been removed.

II.—*Morphological.*—We concluded that in the cat most of the afferent (sensory) fibres of the sympathetic nerves



TEXT-FIGURE 9.—Diagram illustrating the spinal representation or localization of the sympathetic nerve as made very probable from the degenerations following lesions of the sympathetic chain.

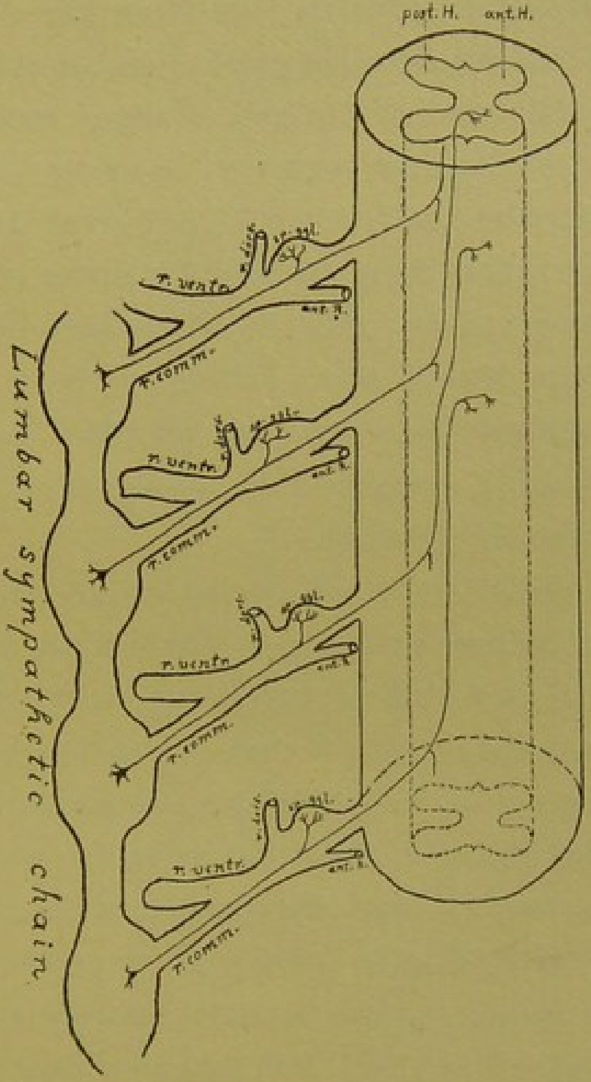
Cl. = Clarke's column.
intm. Z. = Intermediate zone.
Becht. N. = Bechterew's nucleus.
lat. = Lateral horn group.
parc. = Paracentral group.

do not originate from cells of the spinal ganglia, as Kölliker claims, on the contrary they must have (as Dogiel assumes) their cells of origin within the ganglia or plexuses of the sympathetic system.

Our researches make it probable that the efferent fibres of the sympathetic take their origin from the cells of the following groups: 1st, the paracentral group; 2d, the small cells of the lateral horns, and 3d, probably also the small cells of the intermediate zone. The afferent fibres on the other hand are connected by their terminal arborizations with the cells of Clarke's column. Furthermore it is not unlikely that the large cells of the intermediate zone, especially of Bechterew's nucleus, bear the same relationship to the visceral afferent fibres as the cells of the vesicular column. We concede that the entire area between the anterior and the posterior horns has relations to the fibres of the sympathetic (see Text-Figure 9, preceding page), but we do not thereby imply that many of the cells therein have not altogether different functions.

On cross-sections of the cord we saw vertical fibre bundles emerge from Clarke's columns and bend off in horizontal (dorso-ventral) direction; part of them seemed to lose themselves in what we call the paracentral field. These fibres we have much reason to consider *either as direct afferent fibres of the posterior roots or as collaterals thereof.* We have given arguments in favor of the view that these fibres terminate around the small cells of the paracentral group (perhaps also of the intermediate zone ?) and are thus destined for the enactment of spinal reflexes in the domain of the vegetative nervous system.

Very frequently in young cats, and apparently on most levels also in man, Clarke's column and the paracentral cell group coalesce nearly into one group. Probably in the adult cat the separation is also incomplete so that the two may have partially common functions in such manner that some of the cells of Clarke's column (the larger ones) are concerned in afferent, others (the smaller ones) in efferent functions. Similarly the large sporadic cells that one meets in the paracentral group may have afferent, while the smaller ones which form the bulk of the group have efferent functions.



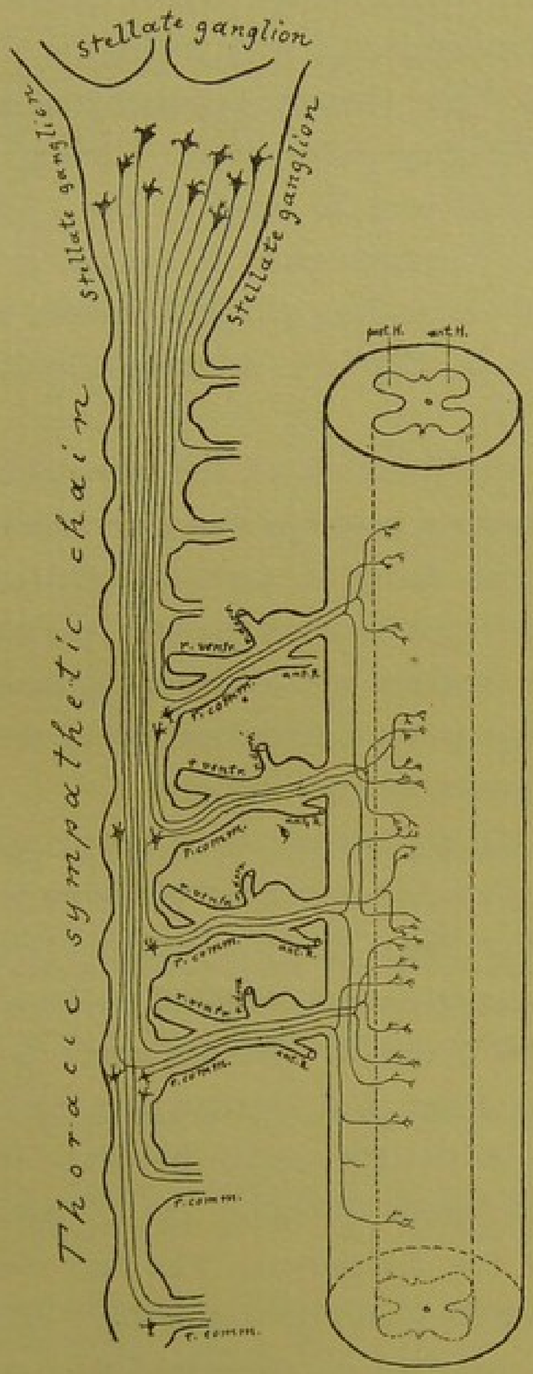
TEXT-FIGURE 10.—Diagram to show the ascent in the spinal cord of the afferent (the efferent fibres probably have a similar course in an opposite direction) fibres derived from the lumbar sympathetic chain, described in the text, pp. 127–8, as resulting from the degenerations following removal of lumbar sympathetic ganglia.

post. H.—Posterior horn.
ant. H.—Anterior horn.
r. ventr.—Ramus ventralis (anterior division) of lumbar nerve.
r. dors.—Ramus dorsalis (posterior division) of lumbar nerve.
sp. ggl.—Spinal ganglion.
ant. R.—Anterior root.
r. comm.—Ramus communicans.

Two weeks after extirpation of the third, fourth and fifth lumbar sympathetic ganglia we observed degenerative changes, both in the cells of Clarke's columns and in the fibres passing into them from the posterior roots. The degeneration in the fibres reaches from the third lumbar up to the thirteenth dorsal segment; on the other hand the inferior (caudal) limit of the cell changes must be looked for in the first lumbar segment, showing that the cell changes occupy on the whole a higher level than the fibre changes; that accordingly the afferent fibres of the lumbar sympathetic nerves entering the spinal cord by way of the posterior roots make, after having arrived at Clarke's columns, a longitudinal course cephalad to terminate around cells of a considerably higher level (see Text-Figure 10, preceding page).

From the distribution of the secondary atrophies observed in the spinal cord four weeks and six months after extirpation, in one case of the seventh (or sixth ?) to the ninth, in the other of the seventh to the eleventh thoracic sympathetic ganglia, in young cats, we concluded that on the whole, the fibres, at least the afferent—probably also the efferent—coming from the ganglia of the lower half of the thoracic sympathetic cord, take a rather horizontal course in the spinal cord to become connected with spinal cells of the same level, but that part of these fibres probably descend either in the spinal cord or sympathetic nerve through the distance of one or more segments, before reaching the cells around which they terminate or from which they originate if it be efferent fibres (see Text-Figure 11).

Extirpation of the stellate ganglion causes within a few months retrogressive changes of an atrophic order in the cells of both lateral horns, of both paracentral groups and of both columns of Clarke. These changes extend downward at least to the ninth dorsal segment showing that



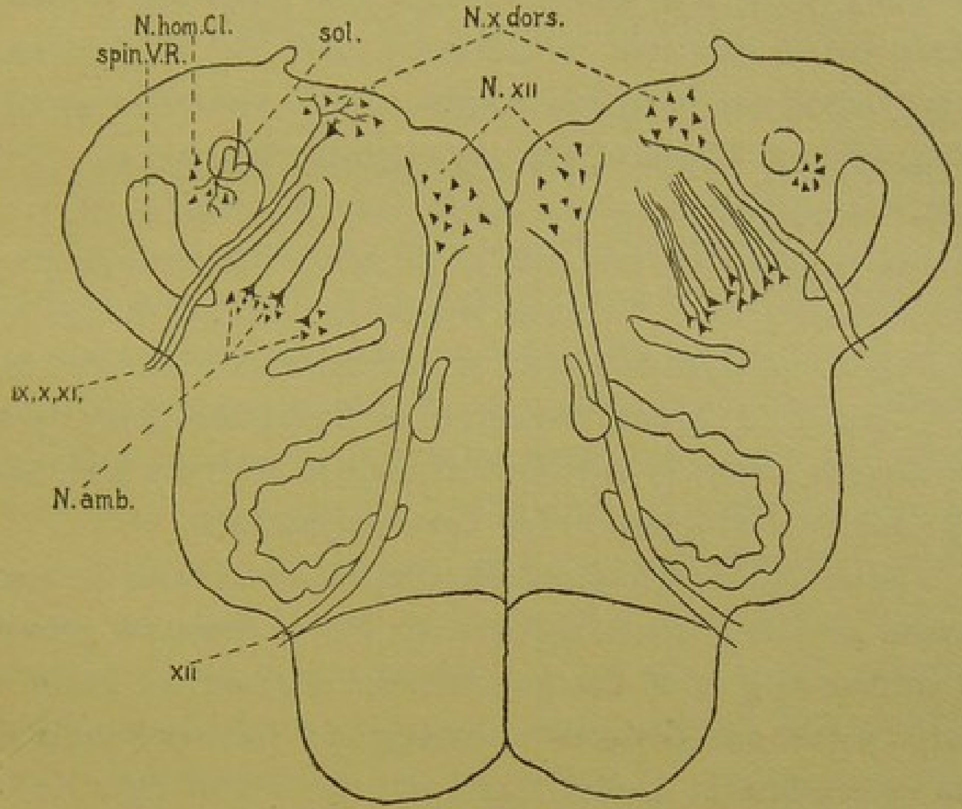
TEXT-FIGURE 11.—Diagram showing the afferent fibres derived from the stellate ganglion and lower thoracic sympathetic chain in their course to the spinal cord. The course is suggested by the degenerations following removal of the stellate ganglion and also the lower thoracic sympathetic chain. The efferent fibres very likely have a similar course in opposite direction.

post. H.—Posterior horn.
ant. H.—Anterior horn.
r. ventr.—Ramus ventralis (anterior division) of dorsal nerve.
r. dors.—Ramus dorsalis (posterior division) of dorsal nerve.
ant. R.—Anterior root.
r. comm.—Ramus communicans.

many of the afferent and also of the efferent fibres from the stellate ganglion probably make a long descent in the cord, or possibly in the sympathetic nerve, becoming connected partly with the same cells with which the fibres from the lower portion of the thoracic sympathetic cord enter connections. We may infer from Ramon y Cajal's investigations that part at least of the afferent fibres of the sympathetic system after T shaped division become ascending and descending and thus become connected with several levels of Clarke's columns simultaneously (see Text-Figure 11).

Regarding the function of the paracentral group, we have suggested its possible vascular function. Clarke's column, besides being a terminal station for afferent fibres from the vegetative organs may be instrumental also in conducting sensory stimuli from the muscles, tendons, joints and bones to the cerebellum being thus largely concerned in maintaining equilibrium.

Regarding the representation of the sympathetic in the oblongata we find that it has not yet been proven that the vago-glossopharyngeal nucleus situated beneath the floor of the fourth ventricle is a terminal nucleus of purely sensory or afferent function. We are much inclined to share the opinion of Forel and Gaskell that the nucleus is predominantly motor in the sense that the neuraxons of its cells become efferent fibres of the IX and X, probably also partly of the XI nerve. The fact that on extirpation of the stellate ganglion—aside from afferent fibres—only visceral (vegetative) efferent fibres and no somatic motor fibres of the vagus nerve which gives off a strong communicating branch to the ganglion, become interrupted, taken in connection with the observation that as a secondary consequence of such lesion the spinal division



Text Figure 12.—Diagram to show the relation of the so-called lateral mixed system of nerves (IX, X, XI root) with the vago-glossopharyngeal nucleus, with the nucleus ambiguus, with the solitary bundle and with a nucleus which we consider to be the homologue of Clarke's column. These relations are suggested among other things by the changes in the oblongata following removal of the stellate ganglion.

N. X. dors.—Dorsal vagus nucleus or vago-glossopharyngeal nucleus, so-called. = nucleus for the visceral or vegetative efferent fibres of the lateral mixed system (IX, X, XI nerves).

IX, X, XI.—Common root of the IX, X, XI nerves (= lateral mixed system).

N. amb.—Nucleus ambiguus = nucleus for the somatic efferent fibres of the lateral mixed system (IX, X, XI nerves).

sol.—Solitary bundle called also trineural fascicle or descending root of the lateral mixed system.

N. homol. Cl.—Nucleus homologue of Clarke's column.

N. XII.—Hypoglossal nucleus.

XII.—Hypoglossal nerve.

spin. V. R.—Spinal trigeminal root.

of the vago-glossopharyngeal nucleus underwent some atrophy while the nucleus ambiguus remained normal, leads us to conceive furthermore, that the vago-glosso-pharyngeal nucleus gives origin only to visceral (vegetative) efferent fibres of the vagus-glossopharyngeal. The nucleus ambiguus gives origin only to *somatic* efferent fibres of these nerves, that is to motor fibres supplying striated muscles. In other words, in relation to the so-called lateral mixed system of nerves (which includes the IX, X and XI nerves) the so-called vago-glossopharyngeal nucleus is probably the visceral (vegetative), nucleus, and the nucleus ambiguus is the somatic nucleus.

The so-called vago-glossopharyngeal nucleus is, furthermore, probably the homologue of the paracentral group. The homologue of Clarke's column we believe to be a large celled nucleus accompanying the solitary bundle at its ventro-lateral border,* (see p. 169). The relation of the *afferent* fibres of the lateral mixed system (IX, X and partly XI nerves) to the two nuclei just mentioned is probably such as we have tried to demonstrate as existing between the spinal visceral fibres on one side and Clarke's column and the paracentral group on the other (see Text-Figures 12 and 9 or 7, also text pp. 157–8).

In accordance with this view the vagus fibres which have been seen terminating in the vago-glossopharyngeal nucleus by van Gehuchten, Kölliker, His, *et al.*, are to be considered as afferent reflex fibres or collaterals, (see pp. 176 *et seq.* and Text-Figure 12).

* Not the gelatinous substance accompanying this bundle.

PART IV.

THE PATHOLOGY OF THE SYMPATHETIC.

CHAPTER XXVI.

THE GENERAL RÔLE OF THE SYMPATHETIC IN DISEASE.

There are a number of diseases characterized by, or attended with symptoms referable to the sympathetic system of such prominence and unvariability that some of them have been considered to be sympathetic neuroses. Other diseases develop sympathetic symptoms early and maintain them conspicuously to the end. Among the diseases that have been in the past, or are to-day classified as diseases of the sympathetic system we may mention exophthalmic goitre, disease of the suprarenal capsules known as Addison's Disease, certain diseases characterized by vasomotor spasm and relaxation or exudation, such as localized symmetrical gangrene, erythromelalgia (?) and angeioneurotic œdema. The diseases of the spinal cord that have prominent symptoms of sympathetic involvement are tabes, syringomyelia and poliomyelitis.

The vegetative nervous system is so intimately associated with the cerebro-spinal system, genetically, anatomically and functionally, that it is not astonishing that a lesion of the one is often attended with symptomatic manifestations in the domain of the other. When diseases accompanied by lesions of the cerebro-spinal system occur with symptoms known to be the expression of functional perversion of the sympathetic, it suggests that the seat of representation of the sympathetic in the cerebro-spinal system is being encroached upon by the lesion. In short, that the concurrence of such symptoms is just as suggestive, and perhaps more so, in pointing out the territory that is being invaded by the morbid process as anæsthesia or atrophy of certain groups of muscles in other diseases is a sign that certain centres or levels in the central nervous system are being involved.

It is for this reason that we have decided to append a brief critical review of the subject of the occurrence of "sympathetic" symptoms, and to inquire into their origin. We shall not aim to do more than enumerate such symptoms as they occur in various diseases and lesions.* The reader may then judge whether the anatomical contributions presented herewith can be utilized to facilitate an explanation of these symptoms. The sympathetic nervous system has been too long a terra incognita, not alone anatomically but clinically. The time, and our knowledge of this part of the nervous system, meagre as it is, await the suggestion that the "vegetative" system of nerves may be diseased independently of the cerebro-spinal system, and that the pathogenesis of such diseases is not unlike that of affections of the latter.

Indeed it seems to us highly probable that eventually the diseases of the sympathetic nervous system will be found to include not a few, perhaps very many indeed, of the now-called functional diseases, not alone the functional "nervous" diseases and "mental" diseases, but many of the general diseases as well, more particularly those that are now attributed to perverted metabolism. As our cases with general and nervous symptoms attributed to defective and incomplete metabolism are more carefully studied, we shall find that they comport themselves like the diseases that have been proven to be dependent upon perversion of the sympathetic system.

* The reader is respectfully referred to an article entitled "Reflections on the Nosology of the so-called Functional Diseases," by Collins and Fraenkel, Medical Record, June 17, 1900, upon which this chapter is partly founded.

The diseases that are attended with symptoms referable to the sympathetic with such prominence and frequency that they require mention are:

- I.—Organic
  - Intracranial
    - Lesions of the thalamus.
    - Lesions of the cerebellum.
    - Lesions of the pons-oblongata.
  - Intraspinal
    - Tabes dorsalis.
    - Syringomyelia.
    - Poliomyelitis (especially acute).
    - Injuries and neoplasms.
- II.—So-called Functional and Peripheral.
  - Exophthalmic goitre (Graves' Disease).
  - Bronzing of the skin (Addison's Disease).
  - Diabetes mellitus and insipidus.
  - Erythromelalgia (Mitchell's Disease).
  - Circumscribed symmetrical gangrene (Raynaud's Disease).
  - Angeioneurotic œdema (Quincke's Disease).
  - Vaso-dermatoses, urticaria, etc.
  - Neurasthenia, not only the pulsating forms, but the neurasthenic state; unilateral, circumscribed anidrosis, and hyperhidrosis.
  - Hysteria; blue œdema.
  - Enteroptosis: Glenard's Disease.
  - The paræsthetic neurosis. Acroparæsthesia.
  - Facial hemiatrophy.
  - Circumscribed and diffuse neural atrophy of the skin.
- III.—Traumatic . . . . . .
  - Direct injury to any part of the sympathetic.

Chapter XXVII.

ORGANIC DISEASES.

Intracranial Diseases.—The intracranial diseases attended with sympathetic symptoms are neither frequent nor common if we exclude the vasomotor manifestations or accompaniments of the inflammatory diseases and the insanities.

Thalamus.—Disease of the thalamus, such as tumor, sometimes gives rise to very striking and suggestive sympathetic nervous symptoms. We may quote a case recorded by Clarke which is in point. The patient showed, in addition to the customary symptoms of intracranial tumor, very marked vasomotor symptoms. Early in the disease there had been loss of control of the bladder. The post-mortem examination showed a tumor of the left lateral ventricle implicating the thalamus, which had subjected it to great compression. We have been able to find a number of such cases on record, associated not alone with neoplasms of the thalamus, but with vascular and sclerotic lesions.

Cerebellum.—Lesion of the cerebellum, whether artificial or the result of disease, is not so frequently accompanied by symptoms dependent upon perversion of the sympathetic system as are lesions of the thalamus. Borgherini and Gallerani have noted that during the first week after ablation of the cerebellum animals show very decided atony of the intestine, and also paralysis of the bladder. In such cases there have likewise been noted well-marked trophic symptoms. It is well known that incontinence of urine is not an infrequent symptom with tumors of the cerebellum, but it has been considered usually to be dependent upon the asthenia, which cerebellar implication invariably produces.

Pons and Oblongata.—The vasomotor, secretory, and trophic symptoms that may occur with lesion of the pons and oblongata are numerous, and they are much more in evidence in disease of the latter than of the former. Excessive secretion of saliva, and in many cases diminished secretion; vasomotor instability, manifested by surface coldness, change of color and temperature; urinary disturbances, evidenced by hurried action of the sphincters, and sometimes by incontinence, occasional glycosuria, are the common symptomatic concomitants of degenerative lesion in the oblongata, especially when the lesion involves the dorsal portion. As such lesion is of the portion of the oblongata which our investigations lead us to believe represents the sympathetic nerve allocation, the occurrence of such symptoms with disease of this part tend to substantiate the experimental conclusions. The polyuria that sometimes accompanies disease of the oblongata has been attributed to involvement of the vasomotor centre for the kidneys, which is supposed to be in the floor of the fourth ventricle in the vicinity of the vagus nucleus, and adjacent to that area which when irritated causes the appearance of sugar in the urine. Clinically, it is of importance to bear in mind that the development of an area of sclerosis, or the deposition of gliotic tissues may be first indicated by symptoms of sympathetic involvement, especially glycosuria. In such cases it would be justifiable to make a topical localization of the lesion to the nuclear region. It is not at all improbable that some cases of facial hemiatrophy associated or not with lingual hemiatrophy are dependent upon organic lesion of the pons-oblongata implicating the cerebral root of the V nerve or the substantia ferruginea and the large vesical cells accompanying the cerebral V root. As a matter of fact no other hypothesis satisfactorily explains all the ancillary phenomena consisting as they do of anhidrosis, pigmentation, alopecia, shedding of the teeth, dilatation of the pupil, grayness of the hair, etc., all on one side, and occasionally tachycardia.

Intraspinal Disease.—It is the occurrence of sympathetic nervous symptoms with spinal diseases that we are particularly interested in, as our investigations bear more directly on the genesis of such symptoms. Two diseases of the spinal cord, tabes dorsalis and syringomyelia are very prone to be attended with conspicuous, oftentimes early, manifestations of functional perversion of the sympathetic. The two other diseases that show such sympathetic symptoms less frequently are anterior poliomyelitis, and the chronic disease which must still be called transverse myelitis. Our search of the literature of tabes and syringomyelia, with the object in view of determining if the presence of sympathetic symptoms with lesions of certain parts of the cord were to be made out sufficiently often to bear evidence on our allocation of the sympathetic tract in the cord, has not been particularly fruitful. This is not because of the paucity of recorded cases, but because of the fact that in many of the cases investigated anatomically very little attention has been given to Clarke's columns and the immediate environmental area. In other cases, the clinical history was not sufficiently clear. We venture to hope that future study of these cases will embrace these points.

Tabes Dorsalis.—All writers on tabes are in accord that vesical symptoms are among the first to show themselves. Usually when the disease is advanced these symptoms consist of incontinence and slight retention, but early in the disease there may be what is apparently too great urinary pressure, or at least frequent micturition and constant desire to urinate.

Ketli believes that the initial disturbance in tabes consists of difficulty of micturition. Patients with tabes do not feel the desire to urinate, as do normal individuals. In other words, their bladders do not respond automatically to the stimulus of normal fulness. Therefore they pass urine with difficulty and only after considerable effort spent in starting the stream. This investigator believes that these disturbances can only be explained according to the reflex theory on the supposition that there is lessened sensation of the bladder walls, which in turn makes the transmission of sensory impulses to the central nervous system, that is to the centre, slower.

The pupillary phenomena which are characteristic of tabes show themselves early and are of great diagnostic, and we believe of prognostic, importance, as well. They occur in upward of seventy-five per cent of the cases, it is believed, although further investigation is needed on this point. The symptoms referable to the eyes that we shall speak of in this connection are the pin-point pupils: myosis spinalis, and loss of the light reflex. The former is supposed to be due to involvement (inhibition, same effect as severing) of the cilio-spinal centre situated in the lower cervical region, or of the representation of the cervical sympathetic in the cord. As the lesion of tabes is uncommon at this level, it has been suggested that the myosis is a "reflex" symptom. According to Budge, the cilio-spinal centre (centrum cilio spinale inferius) begins caudad of the exit of the sixth cervical and ends cephalad of the exit of the third dorsal nerve. According to Langendorff, the cilio-spinal centre is a tonic centre for the dilatation of the pupil. Irritation of the anterior roots of the second and third dorsal nerves, or of the corresponding cord segments from the sixth cervical to the third dorsal nerves, causes dilatation of the pupils, providing the sympathetic is intact. The motor nerves that are involved pass through the rami communicantes to the sympathetic cord. If the sympathetic is separated from the cilio-spinal centre, then there is narrowing of the pupils. After extirpation of the corresponding spinal cord segment of one side there is narrowing of the pupil of the same side. Recently Goldscheider and Leyden have said that it is very questionable if the designation spinalis should be given to the variety of myosis occurring with locomotor ataxia, as it is not very probable that it is caused by affection of the cervical cord. Just why this statement is made the authors do not make clear unless it is that they desire to emphasize that myosis may arise in a number of other ways. It is unquestionable for instance that it may be conditioned through the ophthalmic branch of the V nerve or its central representation. The lesion which causes myosis spinalis may not be of the cervical spinal cord; in fact, as a rule it is not; but it is not infrequently of the dorsal cord, and it represents anatomically a decay of the efferent neurons which pass from the sympathetic system to the paracentral groups and to Clarke's columns.

The vasomotor and trophic disturbances of common occurrence in tabes, which are probably an expression of encroachment of the lesion on the intraspinal sympathetic allotment, are vascular disturbances of one side of the cephalic extremity evidenced by pallor, coldness, hemicrania, etc.; hyperhidrosis, and perhaps in the latter part of the disease, anidrosis; and occasionally epiphora, increased secretion of saliva and intestinal fluxes. Of the trophic disturbances, mention must be made of spontaneously occurring ecchymoses; purpuric and urticaric eruptions; herpes zoster; a peculiar eruption resembling ichythosis; shedding and crumbling of the nails; perforating ulcer, and trophic lesions of the joints and soft parts. Every now and then some writer attempts to explain the occurrence of such symptoms as these by a revivication of the hypothesis of Thierret, who alloted the posterior lateral group of the anterior horns as the origin of the sympathetic; while others make a statement of Stricker's observations that the vasodilator fibres are conveyed in the posterior roots, just as if these were established facts. Among other remarkable statements that Leyden and Goldscheider make in the work already referred to is: That probably the vasomotor nerves arise from the ventral cornua, in which throughout the length of the spinal cord vasomotor centres are scattered! It need scarcely be said that they furnish no evidence of this "scattered" localization of the vasomotor centres.

Glycosuria is an uncommon but still not a very rare accompaniment of tabes. In fifty cases examined by Guinon and Soques, it was not found once. Yet in one hundred and twenty-five cases investigated by Eulenburg, genuine glycosuria was encountered three times. When glycosuria was first discovered to be an occasional accompaniment of tabes, the hypothesis was advanced that the sclerotic process which forms the anatomical basis of tabes had extended to the oblongata and caused irritation of the so-called hepatic centre (Smith, Oppenheim). We hold this an extremely improbable explanation, and much less worthy of consideration than the one that attempts to explain it by positing implication of the sympathetic fibres in the cord—the fibres which Schiff declared would produce glycosuria when severed.

Among the most distressing symptoms of tabes, the first place must be given to the profound attacks of pain localized to some of the visceral organs, such as the stomach, the bladder, the rectum, the gall bladder, the liver and the larynx, to which the name crises has been given. No satisfactory explanation has yet been offered to account for the development of these very peculiar attacks, and although in a number of instances the peripheral nervous system has been carefully examined microscopically, no changes to which the symptoms could be attributed have so far been made out. The most frequent crises are those referable to the digestive organs, gastric and rectal crises. Their clinical features are too well known to require enumerration. Two facts concerning them deserve mention. In the first place, crises of all kinds, whether they be referable to the intestinal tract or to some of the other viscera, are most apt to occur with cases of so-called "high tabes," *i. e.*, tabes associated with lesion of the spinal cord in the cervical region, and second, that these crises may be the initial symptoms of the disease. We have now under observation three patients, in one of which taboid symptoms first manifested themselves by oculo-pupillary phenomena, associated with vasomotor symptoms and laryngeal crises, and in the others a most profound series of gastric crises followed a simple attack of indigestion. Leyden has spoken of two cases in which the gastric crises came on, one after artificial abortion, the other after laparotomy, in both of which the crises were heralding symptoms of the tabes dorsalis. These facts, it seems to us, are of considerable importance in pointing to the intraspinal sympathetic fibres that may be the first to submit to the evil effects of the agencies responsible for tabes, and to the location of the degeneration. Occasionally the gastric phenomenon of tabes is vomiting without pain, a condition to which the name hyperemesis spinalis has been given by Berger. In this condition it is supposed that the fibres conducting sensory impressions are not yet impaired. Next in point of frequency to the intestinal crises are analogous attacks manifested in the bladder and in the larynx and pharynx. As with the crises of the intestinal organs, the occurrence of these is most common with cervical tabes. Their genesis is supposed to be the same, their different areas of manifestation being explained by the different levels of spinal cord implication.

II.—*Syringomyelia.*—Syringomyelia is a disease of comparatively recent recognition, but its advent in medical nosology has been contemporaneous with a period of great illumination of the structure of the central nervous system and, considering its brief history, the disease has been thoroughly studied and its pathogenesis satisfactorily exposed. The trophic and secretory accompaniments are among the most striking of the symptom complex.

Disturbances of the bladder do not occur so often as they do in tabes, but when they occur they are almost always heralding phenomena. Retention of urine is the form that the disturbance usually assumes. Incontinence occurs much more rarely.

The anatomical seat of the disease is oftenest in the cervical region of the cord, and the vasomotor phenomena are usually in the domain of the cervical sympathetic. These are coolness and paleness of one side of the face or the neck and chest, anidrosis, and very occasionally facial hemiatrophy.

Trophic manifestations are more prominent than in any other disease of the central nervous system, even aside from the atrophy of the muscles dependent upon destruction in the substance of the ventral horns, which is the leading feature of the disease.

Although the symptomatology of syringomyelia must be, from the very nature of the pathological process, a more or less variable one, the dictum has apparently gone forth that it is always associated with pathognomonic sensory disturbances, namely, thermoanæsthesia, analgesia, and preservation of the tactile sense. We venture to believe that this dictum will not withstand the test of time, and in support of this belief we would cite the essentials of a case now under observation which we believe justify the diagnosis of syringomyelia, although there are no sensory disturbances.

The patient, a boy thirteen years old, was brought to the Post-Graduate clinic because of a deformity of the right hand which had been slowly progressive since about three years before, when it was first noticed. The history of the boy was that he had passed a moderately uneventful childhood and had gone through the ordinary diseases of this time of life without any ill effects. When he was about nine years old he began to suffer from diarrhœa, which would come on without evident dietetic indiscretion, and which would cease without treatment. Such attacks of diarrhœa have persisted until the present time. There would seem to be no assignable cause for them, nor has examination of the stools thrown any light upon the origin of this symptom. The boy is of customary height for his number of years, but he is pale and ill nourished. Examination of the viscera does not reveal any abnormality. The three striking symptoms, or physical signs rather, which he presents are: narrowing of the right palpebral fissure, slight contraction of the right pupil, the two giving the syndrome of what is commonly called Schultze eye; marked cervico-dorsal kyphosis, with normal pleuræ and lungs, and atrophy of the hand muscles, predominantly those innervated by the ulnar nerve, but somewhat of those muscles innervated by the musculo-spiral nerve. In other words, the boy has the characteristic symptoms and signs of syringomyelia, minus the sensory defects, to which is superadded attacks of diarrhœa. It appears to us that the gradual distension or dilatation, rather, of the central canal, predominantly in an anterior and lateral direction, would cause just such a series of symptoms. It would obliterate, first, the group of cells which we have called the paracentral group, and would give rise to the sympathetic symptoms next the antero-internal group of cells of the internal cornua, which have been proven (Kaiser, Collins, *et al.*) to innervate the back muscles, and finally, the antero-medial group which supplies particularly the fibres of the brachial plexus passing into the ulnar. Naturally, we do not state positively that the lesion is that of syringomyelia. It may as well be a chronic anterior poliomyelitis, but with the conception of a syringomyelia, the course of the disease, and the grouping of symptoms fit in better with the former than with the latter.

Future study of syringomyelia should be particularly directed to accurate observation of the sympathetic symptoms, with especial reference to the time of their appearance, and the extent and location of the destructive process when the cord comes under the eye of the anatomist. The symptoms of sympathetic involvement in syringomyelia are very profound. The hands and arms may be blue and cold. This phenomenon sometimes is more often unilateral than present on both sides. The skin is not infrequently dermographic, and sometimes there appear patches of discrete and confluent erythema. The skin is often cold and moist and in many cases there is alteration of the sweat secretion. Anidrosis or hyperhidrosis may occur and the distribution of this secretory disturbance seems to have a predilection for those areas that show the peculiar sensory dissociation and analgesias.

Very rarely there are acute trophic manifestations in the skin, such as glossy skin, the formation of bullæ and transformation conditions resembling the early stages of scleroderma. Occasionally the skin and the subcutaneous cellular tissue is the seat of œdema, and in very exceptional instances a state resembling local asphyxia has manifested itself. The trophic accompaniments may take on a profound degree of severity and be evidenced as phlegmon, perforating ulcer, loss of the hair, nails, etc. These symptoms all bespeak implication of the cell groups of fibres of the sympathetic in the cord.

Glycosuria occurs with syringomyelia even oftener than with tabes, and until the present time no satisfactory explanation of its occurrence has been given.

We must here remark that we have endeavored to determine from a review of the published cases of tabes and syringomyelia whether the presence in these cases of visceral and trophic disturbances coincided with the occurrence of lesion in definite regions of the spinal cord, but the results of the review were unsatisfactory. Either the clinical history of the patient was given in an incomplete fashion, or the description of the morbid changes was not exact enough to aid us in determining whether lesions of these fibres or cells caused disturbance of the bladder, crises, etc., or trophic manifestations.

Spinal Compression Caries, and the Oculo-pupillary Symptoms.—It is not alone in tabes that oculo-pupillary symptoms occur. In a case of compression of the cervical spinal cord reported by Krauss these symptoms were so prominent that a diagnosis of involvement of the cord predominantly of the first dorsal segment was made. This diagnosis was confirmed by autopsy and by microscopical examination. In cases of compression of the cord in the cervico-dorsal region myosis is a much commoner accompaniment than mydriasis, and cases might be quoted at great length in support of this statement if it were not thought that citation of such evidence was superfluous.

The complex of sympathetic symptoms usually spoken of as the "oculo-pupillary phenomenon" is a common accompaniment of spinal caries, particularly when the tuberculous process involves the lower cervical and upper dorsal vertebræ. The symptoms consist of myosis (the pupil still preserving the capacity of reaction), narrowing of the palpebral fissure, and retraction of the eyeball. All of these symptoms are not present in every case. Myosis is the commonest; indeed it may be the only one to be present. Frequently the oculo-pupillary phenomena are unilateral, but they may and do occur on both sides. Hutchinson was among the first to show that oculo-pupillary fibres pass to the sympathetic through the rami communicantes, and he attributed the oculo-pupillary symptoms to involvement of these fibres. Recently Madame Dejerine-Klumpke has shown that section of the last cervical and of the first dorsal nerves at the level of the first dorsal intervertebral space causes the appearance of oculo-pupillary phenomena without accompanying vasomotor symptoms. Some writers believe that oculo-pupillary symptoms are root symptoms, and are more apt to occur unassociated with any other symptom, with lesion of the spinal roots than with lesion of the spinal cord; and as we have said in a previous connection, Claude Bernard and Dastre and Morat, have contended that if vasomotor symptoms accompany the oculo-pupillary phenomena, the disease process that gives rise to them implicates the dorsal region of the cord to a greater extent than if the latter occur alone. They hesitate, however, in putting a topographical limit upon the vasomotor fibres, but they locate unhesitatingly the cilio-spinal centre. Clinical and experimental evidence concur in corroborating very closely the localization of this centre as originally given by Budge.

CHAPTER XXVIII.

TRAUMATIC DISEASES OF THE SYMPATHETIC.

Injury of the Cervical Sympathetic.—The following symptoms have been observed to occur after injury to the cervical sympathetic in man: (1) Narrowing of the pupil; (2) Narrowing of the palpebral fissure; (3) Retraction of the eyeball; (4) Lessened tension of the eyeball; (5) Redness of the surface and elevation of the temperature of the ear and face of the affected side; (6) Hyperhidrosis, anidrosis; (7) Increased secretion of saliva; (8) Hemiatrophy of the face; (9) Bradycardia; (10) Headache, nervousness, and cephalic pressure.

Narrowing of the pupil is the most common and constant accompaniment. Nicati, who gave much attention to the study of this phenomenon, says that the pupil is narrowed to one-third or one-half its original size. The shape of the pupil remains round or slightly oval. It reacts to light, but somewhat less promptly than in the normal state. Rieger and Forster say that this fact indicates a paralysis of the dilator fibres, a paralysis of the antagonist. This has been refuted by Möbius, but the latter's assumption of rigidity of the sphincter analogous to paralytic contracture is also unsatisfactory. In Möbius' case the pupil of the normal side could be dilated by the application of the faradic current to the cervical sympathetic of the affected side.

The less prompt reaction to light can well be explained by what our researches have made very probable, namely that the cervical sympathetic contains also pupil contracting fibres. On the other hand it should not be forgotten that there are pupil-dilating fibres going to the pupil from the first branch of the trigeminus. Reaction of the pupil remains preserved even if the cervical sympathetic is entirely severed. Jendrassik says that the sympathetic dilatation is something of its own and independent of dilatation due to removal of light, and this explanation seems to us very plausible.

The interesting experiments of Fischer, who excited the cervical sympathetic nerve in the heads of two decapitated individuals, may also be mentioned here, as they have a decided bearing on this point. Fischer observed that faradic excitation caused opening of the palpebral fissure, dilatation of the pupil, protrusion of the cornea and considerable lachrymal secretion.

The narrowing of the palpebral fissure accompanying injury of the cervical sympathetic is due to paralysis of Müller's muscle of the lid. In most cases, the lower lid reaches higher over the ocular surface than the upper, and higher than the lower lid of the unaffected side. The retraction of the eyeball has been referred by Nicati to reduction in size of the eyeball, to atrophy of fat in the orbit, and to paralysis of Müller's muscle. The first explanation attributing the retraction of the eyeball to reduction of its size deserves attention, because it harmonizes with the result of Angelucci's researches who found that extirpation of the stellate ganglion in new-born dogs was followed by diminution in size of the eyeball in all its diameters. The second explanation of Nicati which assumes an atrophy of the fat cushion of the orbit, although presenting a novel and rather strange view, should not be rejected offhand, especially if we keep in view the ocular dystrophies such as plaques of atrophy and sclerosis observed by Angelucci in the choriodea and iris of cats deprived of the stellate ganglion. Angelucci attributes these dystrophies to changes in the blood vessel walls and it does not seem impossible that the fat tissue might also undergo changes under the influence of the diseased sympathetic. It is very probable that the third factor given by Nicati, namely the paralysis of Müller's muscle, plays the most important causative rôle in the retraction of the eyeball from lesion of the cervical sympathetic. According to Baerwinkel, the retraction of the eyeball is the result of decreased tonus of the supraorbital artery, the central artery of the retina and the ciliary artery, but this theory has been refuted by Möbius. We may mention in this connection that the last named author has established, statistically, that most cases of retraction are associated with hemiatrophy of the face. It is appropriate to cite again Heese's experimental investigations in this connection. According to this author the influence of the cervical sympathetic on the eye is twofold, namely, first, vasomotor; second by contraction of Müller's muscle, the former giving rise to sinking in, the latter to protrusion of the eyeball. On exciting the cervical sympathetic nerve in cats, the effect upon Müller's muscle predominates over the vasomotor influence, therefore protrusion, while in rabbits the condition is quite the reverse.

Nicati described three stages of paralysis of the cervical sympathetic nerve. In the first stage there is intense reddening of the affected side, associated with elevation of temperature and hyperhidrosis. In the second stage there is moderate hyperæmia of the affected side, and in the third stage pallor. According to Seeligmüller and Möbius, this division into stages or this division of stages, does not receive the corroboration of clinical experience. Moreover, Jacobsohn has described a case in which distinct pallor set in immediately after the injury.

Hyperhidrosis has been attributed to dilatation of the vessels, and anidrosis to contraction of the vessels. This contention is not founded on fact. Sweat secretion is to a high degree independent of vascular condition. Adamkiewicz, Vulpian, Luchsinger and others have striven to show that the secretion of sweat is conditioned by an independent set of nerve fibres.*

Another very constant accompaniment of injury to the cervical sympathetic is increased production of saliva, the interpretation of which is by no means easy. We may refer the reader to the discussion on this subject on pp. 62 to 64. Hemiatrophy of the face has been observed occasionally, but, only after lapse of considerable time.

Bradycardia has been noted in a few instances by Möbius. In some cases of injury to the vagus it has been remarked that the action of the heart has not been at all affected. In fourteen cases of cervical vagotomy Veibel found that the function of the heart remained unimpaired, and results similar to these have been recorded by Weidner. In cases of this kind the explanation suggested is that other nerves act vicariously. Some observers have found the pulse rate increased, tachycardia (Traumann). This tachycardia lasted only a short time, after which the pulse rate became normal again. A fact worthy of mention here, is that it has been claimed that the vagus of the right side has greater inhibitory power than the vagus of the left (Arloing and Tripier, Eichorst).

Hirsch has recently reported a case in which the symptoms of injury to the cervical sympathetic were, in connection with other evidence, diagnostic, in spite of the patient's statement: A man shot himself accidently in the

* For Matthews' researches putting the theory of secretion on an altogether different basis, see foot-notes pp. 55 and 57.

mouth. The bullet entered the hard palate, and, according to the patient's statement, and to that of the family, made its exit on the left side of the nose near the orbit. Soon after this, the patient developed the following symptoms: harshness and roughness of the voice, and eventually aphonia; complaint of defective vision in the left eye, and of excessive secretion of saliva. Examination showed that the pupil of the left eye was only two-thirds the size of the right, but both pupils reacted to light and in accommodation. The left eyeball, although of normal tension, was very much sunken. There was no difference in the color, sensibility, or nutrition of the two halves of the face, but there was decided atrophy of the left half of the tongue and complete paralysis of the left vocal cord. There was persistent tachycardia, the pulse beat being 108. Although the patient was sure that the bullet had passed out, a skiagraph revealed it at the level of the spinous process of the fourth cervical vertebra, embedded in the sterno-cleido-mastoid muscle, and it was easily removed.

Thus it will be seen that on the whole the symptoms of cervical sympathetic injury in man are practically the same as those that may be produced by corresponding experimentation on the lower animals. This is a matter of much importance as indicating the homologous structure.

Chapter XXIX.

FUNCTIONAL DISEASES.

If we turn now to a brief consideration of the so-called functional nervous diseases, we shall find that many of them, although attributed and apparently due to disease of certain glands whose function is still unknown, may also be considered primarily disorders of the sympathetic nervous system and that the changes in the aforesaid glands may be regarded as consequent and incidental to such disorder of the vegetative system.

Graves' Disease.—The phenomena of Graves' Disease are too well known to require mention. The secretory and vascular phenomena form an integral part of the disease and are quite as constant as the cardinal triad: exophthalmos, tachycardia, and goitre. Symptoms of uncommon occurrence are glycosuria (Dumontpellier, Ranas) and hurried action of the vesical sphincter, leading to incontinence (Séguin).

Although a great number of theories have been advanced to explain the pathogenesis of Graves' Disease, such as the sympathetic theory, the thyroid theory, the cardio-vascular theory, the auto-infectious theory, etc., they all have one very important thing in common, and that is, that the injurious agencies act through the sympathetic nervous system; in other words, that the mechanism of the symptoms is through the sympathetic.

Recently a novel theory has been propounded by Riche. His hypothesis is that a condition analogous to circoid aneurism dilates the thyroidien vessels, and thus modifies the circulation. "One readily conceives that these vessels, in intimate relationship with the cervical sympathetics, on being excited, call forth the clinical tableaux of the disease." The goitre is the result of the dilatation of the thyroid vessels. This excites the cervical sympathetic with which the inferior thyroid artery is in intimate contact, the result being tachycardia, and later, exophthalmos. The other symptoms of the disease are dependent directly upon irritation of the sympathetic, or upon defective circulation which causes a relative anæmia. The cerebral troubles or symptoms are thus dependent upon cerebral anæmia. In short, according to this writer, excitation of the cervical sympathetic is a complication which may occur with any form of goitre, but which is especially prone to occur with the vascular forms. Such complications constitute the characteristic symptoms of Graves' Disease. He believes that the volume of the gland, its connections, and the internal secretion, do not play any rôle in the pathogenesis of this complication. The goitre is determined by the modification that goes on in the calibre and the circulation of the inferior thyroid artery which stand in such intimate relationship with the cervical sympathetic. This theory has just enough likelihood in it to make it plausible, but it is the most fanciful and least provable that has so far been propounded.

At the present day, as we have said above, it is generally taught that the original disturbance conditioning the symptoms of Graves' Disease is in the sympathetic system, and that the phenomena of hyperthyroidation are in a measure, epi- and coincident phenomena. The poisoning that results from a perversion of function of the thyroid glands, an excessive secretion, is supposed to act upon the medulla oblongata, particularly upon the sympathetic representation therein. Experiments on animals, as well as morbid findings in fatal cases of Graves' Disease seem to point to this conclusion. In a case studied by Grube, there were found small hemorrhages in the oblongata and pronounced congestion along the floor of the fourth ventricle. In two cases examined by Dana (not yet published, verbal communication) there have been found very striking anatomical changes in the oblongata, along the floor of the fourth ventricle. We are far from attaching great importance to every departure from normal that may be found in the oblongata in these cases, and we fully realize that some of them may be accidental, and merely dependents of functional disturbance. Nevertheless, recent histological technic has shown that they are of greater importance than has previously been thought. Gowers says it is possible that some of the cardiac disturbance is produced through the agency, not of the sympathetic, but of the vagus. It is well here to bear in mind that Jendrassik has recently contended for the admission of the vagus to the sympathetic system and its removal from the domain of the cerebro-spinal nerves. If this be allowed, it will be recognized that no essential discrepancy exists in these views.

Concerning the morbid findings in cases of Graves' Disease, Möbius has recently written: "All sorts of conditions have been described; the ganglia are too large or too small; the nerve too thick or too thin; there is too much connective tissue, or too few nerve cells; the nerve cells are deformed, shrunken, or pigmented; there are small hemorrhages, destruction of nerve fibres, etc., etc." To all of which we make an affirmative, choosing to disregard the writer's attempt at irony. We have learned in recent years that in individuals dying of long-standing nervous disease, the so-called functional as well as organic, there are almost invariably, especially if the individual be somewhat advanced in years, retrogressive changes in the nervous system. Although Möbius comes to the conclusion that in the majority of cases of Graves' Disease nothing characteristic or essential is to be found in the cervical sympathetic to explain the pathogenesis of the disease, it does not seem to us that investigation of the vegetative system of nerves in its peripheral and central distribution have been sufficiently comprehensive to give tenability to his position.

In concluding the discussion of this subject the writers wish to present the following points for consideration. In the first place we do not assume that the etiology of Graves' Disease is always uniform. In different cases different factors are active.

It can not be denied that the sympathetic system is involved in the disease, but just what part of it is affected in each particular case and where the primary cause lies may be very difficult to tell. To account for all cases by a local affection of the cervical sympathetic nerve is certainly erroneous since in many cases the symptoms point to other parts of the sympathetic system as the locus peccans. The diarrhœa, for instance, can hardly be explained by lesion of the cervical sympathetic. If peripheral at all, it points to involvement of the splanchnic nerve or solar plexus or other nerve plexuses. Therefore, if the sympathetic system is the primary seat of the disease it must in many cases be more generalized, affecting many regions simultaneously. That there are cases,—we do not confine ourselves to Graves' Disease in making this statement,—in which the general vegetative nervous system is at fault no one can deny; we cite for illustration a patient observed by one of us who at different periods suffered from enteritis membranacea, marked vasomotor disturbances such as local asphyxia and œdema of the hands and the peculiar phenomenon of almost constant profuse milk secretion without pregnancy, thus showing perversion of three vegetative functions. In these cases the vegetative innervation need not be constantly disturbed, but relatively slight causes are often sufficient to unbalance it. Frequently such causes in other individuals produce different effects, attack other points of the organism, thereby showing a tendency in the patients first mentioned to react with disturbances of vegetative innervation to all sorts of disturbing causes. There is, in other words, in many cases a vulnerability of the entire vegetative nervous system. The writers are much inclined to attribute this vulnerability to a peculiar chemical constitution of this part of the nervous system. Given this vulnerability of the vegetative nervous system it is readily seen that if in a given case a source of constant irritation acting upon the vegetative nervous system exists it may lead to progressive symptoms such as we observe in Graves' Disease. That this source of irritation is sometimes a toxic agent seems very probable, and the fact that administration of thyroid makes many cases worse favors the view that in such cases the hyperthyroidation plays an important etiological rôle. However this irritation may also be a psychical one and we wish, in this regard, to point out the similarity which the physiological effect of emotions bears to the picture of Graves' Disease. The look of fright certainly bears in itself the rudiments of the look of exophthalmic goitre and fright is often accompanied by palpitation, by tremor, often by perspiration and diarrhœa, a syndrome characteristic of Graves' Disease.

Anxiety, an emotion akin to fear, produces a similar syndrome. In many cases of Graves' Disease long continued anxiety incident upon nursing dear relatives or from similar causes has in our experience played an important etiological part.

If the relation of the central nervous system to vegetative innervation is kept in view, we may also easily conceive how focal affections involving the centres of the vegetative or visceral nerves may produce many of the symptoms of Graves' Disease and we do not doubt that the lesions of the oblongata found in a number of cases, as quoted above, are responsible for the symptoms present. The progressive tendency might in many a case be due to the paralysis of inhibitory nerve centres which, if permanent, would readily account for the progressive course.

Addison's Disease.—The symptom complex to which the name Addison's Disease has been given is one that does not yet rest on a firm anatomical basis. It is encountered with disease of the suprarenal bodies and with intact suprarenals. That it is not a disease of the suprarenal bodies in the strict sense of the term would seem to be proven by the fact that there may be extensive, if not complete destruction of these glands without the occurrence of the symptoms characteristic of and generally accompanying this disease. Lewin found about twelve per cent of his cases were without obvious disease of the glands. These cases he attributed to alterations of the neighboring sympathetic ganglia, the semilunar and abdominal sympathetic, and many other investigators have attempted similar explanations, but no positive proof can be offered that this is the real cause of the disease. Recently Adami has said in discussing this question that he has very little patience with holders of the sympathetic theory; for scarce two of them describe the same order of lesions, and most of the changes described would appear to be quite common in the adult dying from other causes. An important piece of evidence as to the comparatively slight value that can be attached to microscopic changes in the semilunar ganglia post-mortem has been furnished by Hale White who found in examining thirty-three semilunar ganglia taken from persons dying from different causes that most of them showed degenerative changes.

Those who have attempted to show the dependency cf

Addison's Disease upon the sympathetic nervous system, have, it seems to us, shot wide of the mark in not having a rational conception as to how the sympathetic may act in this problem of pathogenesis. Experiments on animals, it seems to us have shown one thing concerning the supra-renal capsules, and that is that when they are removed, some, at least, of the symptoms that follow are due to the absence of internal secretion, or to the accumulation in the system of substances acted upon by the internal secretion. Now the sympathetic nervous system probably controls this internal secretion in a way similar to its control of the salivary secretion and the secretion of the thyroid glands. In this way it may be held indirectly responsible for variations extending up to pathological degrees in this internal secretion. It by no means follows that the semi-lunar ganglia must be the seat of disease microscopic or macroscopic. On the contrary, remote parts of the sympathetic may be the field of operation of the agency that manifests its injurious activity on the secretion of these glands. In this way might be explained the occurrence of the phenomena of Addison's Disease with different pathological processes.

Acromegaly.—Acromegaly has been classed among those diseases which are attributed to disturbed internal secretions, such as myxœdema and possibly Addison's and other diseases. At the present day few if any physiologists deny that the infundibular lobe of the pituitary body produces an important internal secretion. According to Brooks* the increase of this secretion is accompanied by striking and serious disturbances of nutrition which constitute in their completed or finishing stages the condition known as acromegaly. We have called attention to the

* Acromegalia. ARCH. OF NEUR. AND PSYCHOPATH., V. I, p. 485, 1898. See especially Chapters IX, X and XI.

possible causative rôle which the sympathetic may have in the perversion of internal secretions in Addison's Disease, and a similar explanation might hold good for acromegaly. We would assume in the latter instance that particularly that part of the sympathetic system is the seat of the disease which is connected with the pituitary gland. This view has recently been advanced by Fränkel and Collins. This is of course a hypothesis which will require extensive researches for verification, especially pathologicico-anatomical in the domain of the sympathetic.

Glycosuria.—Glycosuria is a condition that occurs with a great variety of pathological conditions, which may or may not implicate the sympathetic nervous system. That lesion of this system is often responsible for its existence is generally admitted. Ever since its recognition, and particularly since Claude Bernard showed that irritation of the floor of the fourth ventricle, the so-called hepatic vasomotor centre, caused glycosuria, evidence has been accumulating to show that the production of grape sugar may stand in causal relationship to the sympathetic nervous system. The direct and indirect evidence, pathological and clinical data, is now very considerable. Schiff was the first to show that section of the vasomotor channels in the spinal cord at any level down as far as the exit of the nerves for the liver cause glycosuria. It was noted by Pavy that destruction of the superior cervical ganglion caused glycosuria, and by Eckhard that a similar condition resulted when the inferior cervical ganglion and the first thoracic ganglion were destroyed. Trambusti showed that after extirpation of the cœliac plexus there was a deposition of glycogen in the kidneys. It has been pointed out by Klebs and Munk that lesion of the abdominal sympathetic is often accompanied by glycosuria, and by Henderson that lesion of the splanchnic nerves causes the same condition.

A number of hypotheses have been advanced to explain the occurrence of glycosuria with lesions of the sympathetic nervous system produced experimentally, and with those diseases the leading clinical feature of which is derangement of the tonus of the blood vessels—a property of the circulation contributed to by the sympathetic. These hypotheses have been the less convincing because of our ignorance concerning the source and chemico-physiological genesis of glycogen and grape sugar.

Most writers contend that the immediate effect of injury of the different components of the sympathetic, such as those that have been previously enumerated, and that are known to be followed by glycosuria, is to produce a dilatation of the hepatic blood vessels. According to Luchsinger (quoted from Hermann) this vaso-dilatation might cause the blood to pass so rapidly through the liver that the latter does not have time to convert all or enough of the sugar into glycogen. The blood becoming thus loaded with sugar, the latter makes its appearance in the urine. Hermann assumes as the most plausible interpretation of diabetes, a change of the liver or of other organs by which their ability of retaining (festhalten) sugar by its conversion into glycogen becomes lost and by which the glycogen present already in such organ is retransformed into sugar.

It has been shown experimentally that stimulation of the thoracic sympathetic ganglia is followed by a contraction of the vessels of the liver lobules and a paleness of the liver. This condition seems to be one that is inimical to the production of sugar. But it does not follow from this that the occurrence of sugar is not immediately dependent upon mechanical causes as this would apparently indicate. It seems to us much more probable that the sympathetic has a direct regulating influence on the amount of glycogen that the liver produces, and that deviations from the normal are conditioned through the sympathetic system.

The Vasomotor Neuroses.—A group of diseases included under the heading of the vasomotor neuroses constitutes one of the obscurest chapters in medical science. They may include as has already been said, erythromelalgia, angeioneurotic œdema, Raynaud's disease, different forms of vasodermatosis, the paræsthesic neurosis, etc. We have no intention of discussing these subjects in detail here, as we purpose an explicit inquiry into their pathogenesis later. In this connection we desire only to make some general remarks concerning their relationship to the sympathetic nervous system. The position which these affections occupy in the nosology of disease has not yet been determined. The fact that vasomotor phenomena are the basic symptomatic manifestations of all of them have caused them to be looked upon as diseases or functional perversion of the sympathetic nervous system. The fact of the matter is that heretofore pathologists have seemed unwilling to admit that the sympathetic nervous system is capable of responding to the same degrees and varieties of disease as are the other tissues of the body. Eventually, we believe, it will be shown that all of these now so-called functional nervous diseases are in reality diseases dependent upon lesions of the sympathetic nervous system. That this has not already been demonstrated may be due in part to our ignorance of the central anatomical position and relationship of the sympathetic system, for the efforts that have been made heretofore to interpret the pathogenesis of these diseases have been expended exclusively on different levels of the peripheral sympathetic system. We would not be understood as contending that these diseases are always due to organic change in the sympathetic system. Most of these diseases are of comparatively brief duration, but they all, almost invariably, recur. That is, the first attack is rarely the last, and if it is, some other manifestations of the functional disorder is its natural successor. The fact that in the interim the individual may be entirely well tends to support the position that the symptoms are not always dependent upon organic change. In one sense of the word it must be conceded that this class of diseases is entitled to the designation "functional." In fact, the conditions that have been met with so frequently as to warrant us in positing them as causative or predisposing to the individual diseases constituting this class, seem to indicate that the symptoms are due to the perversion of function, and not to organic disease, for in reality they are those that contribute to aberration of what we may call the nutritive balance.

All this is preparatory, however, to the statement that the symptoms accompanying them are mediated by the sympathetic system and are in the main the result of injurious agencies acting upon it. One factor that prompted us to allude to this class of diseases was that we might suggest that the above mentioned injurious agencies may act not only upon the peripheral sympathetic system, but upon the central nervous system: the sympathetic symptoms indicating the encroachment of the disease process upon the central allocation of the sympathetic system. This of course takes for granted that we have proven by the experiments recorded in this monograph the reality of such localization. This explanation accounts for the occurrence of some if not all of these vasomotor disorders with lesions of the central nervous system, such, for instance, as Raynaud's disease, erythromelalgia, etc., with tabes, syringomyelia and myelitis. Naturally, we do not say that the vasomotor neuroses do not occur with lesions of the peripheral sympathetic, in fact, we are in possession of incontrovertible evidence of such occurrence. For instance, in a case of Raynaud's disease described by Collier, little doubt can exist that the symptoms were the immediate result of compression of the sympathetic ganglia in the abdominal cavity by ancient and firm adhesions.

Angeioneurotic œdema furnishes the most exquisite type of a serous exudation secondary to vasomotor influence. It is likewise the purest of the vasomotor neuroses, as all its symptomatic accompaniments are explainable on the ground of such involvement alone. Nothing positive is known of the pathogenesis of this disease, save that its occurrence is markedly predisposed to by anything that lowers vasomotor tone, such, for instance, as the effects of nicotine.

In neurasthenia, hysteria, and the paræsthesic neurosis (acroparæsthesia of the Germans), the sympathetic phenomena are in all probability an expression of an asthenic condition of the general nervous system, sympathetic as well as the cerebro-spinal. Consequently there are aberrations of function in the sphere of each.

ADDENDUM.

It had been our intention—as announced in the foot-note, page 4—to conclude our work with a chapter on the sympathetic in insanity. However, unexpected obstacles, both to the work of the Institute in general, and to the course of publication of our own work especially, have prevented the fulfillment of this promise. The work planned in this regard is still in an unfinished state, unfit for publication, and, in order not to further delay the issue of the monograph and of the ARCHIVES we have decided to postpone the issue of the chapter on the sympathetic in insanity, expecting to issue it in a separate paper. In taking this step we have been influenced not a little by the fact that our researches, although published only in the form of an abstract, have already been quoted in at least two publications come to our notice (van Gehuchten's researches on the vagus nucleus which appeared in the "Traveaux du Labaratoire de Neurologie" publiés par A. van Gehuchten, Année 1898 deuxième fascicule, page 275, and the investigations of Lapinski and Cassirer on the spinal origin of the cervical sympathetic nerve published in the "Deutsche Zeitschrift für Nervenheilkunde," 1901, p. 137) and we may be justly reproached for withholding the original researches furnishing the basis of the abstract above mentioned. Indeed Cassirer and Lapinski, quoting in extenso the result of our investigations, mention regrettingly that they could nowhere find the original publication of our researches, although diligently seeking for it, and that, in the absence of a detailed account of our methods and in the absence of illustrations and other particulars they have to refrain from discussing them. We find under these circumstances that we have no right to further postpone the publication of our investigations.

The authors on revising their MS. now so belated in publication, desire to acknowledge the aid which they have received from Dr. Ira van Gieson, the Director of the Institute. With tireless energy and matchless enthusiasm he has gone over every paragraph. We, as well as the monograph have profited by his criticism, and therefore we are grateful. We beg also to acknowledge our appreciation of the pictorial equipment furnished the monograph. The reader will probably agree with us in saying that it has rarely been excelled in this country.

A series of lectures entitled "The Nervous System and Visceral Diseases," by Alexander Morison, Edinburgh, 1899, has been read by us with much gain.

B. ONUF,
JOSEPH COLLINS.

CHRISTMAS, 1900.

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INDEX.*

* Italic page numbers apply to such pages which are particularly important for the subject to which they refer.

Page numbers placed in parenthesis = ( ) apply to foot-notes.

DESCRIPTION OF PLATES.

Plate I.

Figure 1.—Section of stellate ganglion of a normal young cat. Double stain, carmine—Pal.

cps.=pericellular capsula with nuclei.

med.=medullated fibres.

non.=nonmedullated fibres.

Figure 2.—Section of normal ganglion of the thoracic sympathetic cord in the cat. Nissl stain.

Plate II.

Figures 3 and 4.—Second lumbar segment of a young cat (Case No. 411, Pathological Institute) in which the 3rd, 4th and 5th lumbar sympathetic ganglia on the left side had been extirpated two weeks before death. The pictures show degeneration of posterior root bundles (P. R.) as they pass into Clarke's column. Changes bilateral.

Cl.=Clarke's column.

c.=central canal.

P. R.=posterior root bundles to Clarke's column.

P. C.=posterior column.

For other details see text, pp. 120–123.

Plate III.

Figure 5.—Normal column of Clarke in cat. First lumbar segment. Nissl stain.

Cl.=Clarke's column.

c.=central canal.

Figure 6.—Young cat, in which the 3rd, 4th and 5th lumbar sympathetic ganglia had been extirpated two weeks previous to death (Case No. 411)—1st lumbar segment, proximal end; figure shows atrophy of the cells of Clarke's column, chiefly on one side (r. side of the picture). Nissl stain.

Cl.=Clarke's column.

c.=central canal.

See text, pp. 124–126.

Plate IV.

Figure 7.—Normal young cat; lower dorsal region—showing on the right side of the picture the paracentral group and Clarke's column coalesced into one group. Nissl stain.

Cl.=Clarke's column.
c.=central canal.
parc.=paracentral group.

See also text, pp. 140–141.

Figure 8.—Normal young cat; lower dorsal region—showing, on the left side of the picture, the paracentral group (parc.) as a well defined nucleus distinctly separated from Clarke's column. (Cl.) Nissl stain.

Cl.=Clarke's column.
parc.=paracentral group.
c.=central canal.
lat.=lateral horn group.

See text, pp. 140–141.

Plate V.

Figure 9.—Lateral-horn group of the normal cat. Longitudinal section through the XI and XII dorsal segments.

Figure 10.—Atrophic right lateral-horn group in longitudinal section of the XI and XII dorsal segments. Cat registered as Case No. 415 of the Pathological Institute. When the animal was six weeks old the 8th, 9th, 10th and 11th thoracic ganglia of the right sympathetic cord were extirpated, together with the intervening internodial rami and the adjoining piece of the splanchnic nerve.

Cat sacrificed six months after operation.

See text, p. 140.

Figure 11.—Longitudinal section through the paracentral group of the XI and XII dorsal segments of a normal cat.

Figure 12.—Longitudinal section through the paracentral group of the XI and XII dorsal segments of a cat in which the 8th, 9th, 10th and 11th thoracic ganglia of the right sympathetic were extirpated (registered as No. 415 of the Pathological Institute). Cat sacrificed six months after operation.

ep.=ependyma of central canal.

See text, pp. 141–142.

Compare the normal paracentral group of cells in figure 11 with the atrophic group in figure 12.

Plate VI.

Figure 13.—To illustrate a horizontal bundle (P. R.) (probably the continuation of a posterior root bundle) passing into the column of Clarke to become vertical (P′ R′). Cat. 8th dorsal segment. Pal.

Cl. = Clarke's column.
c. = central canal.
P. R. and P′ R′. = Horizontal bundle probably of posterior root.

See text, p. 148 et seq.

Figure 14.—Illustrating paracentral field and Clarke's column. Cat, 8th dorsal segment. Pal.

PARC. = paracentral field.
Cl. = Clarke's column.
c. = central canal.

See text, p. 148 et seq.

Plate VII.

See text, p. 148 et seq.

Figure 15.—Showing vertical fibres of the paracentral field bending in horizontal direction and entering Clarke's column. 8th dorsal segment, cat. Pal.

PARC. = paracentral field.
rfl. = bundle of reflex fibres.
Cl. = Clarke's column.
c. = central canal.
ant. col. = the portion of the anterior column which is adjacent to the anterior commissure.

Figure 16.—Showing vertical fibres of Clarke's column bending dorso-ventrad and passing into the paracentral field. 8th dorsal segment, cat. Pal.

PARC. = paracentral field.
Cl. = Clarke's column.
c. = central canal.

Plate VIII.

See text, p. 148 et seq.

Figure 17.—Showing the termination of a fibre (f) on the body of a cell of Clarke's column.

8th dorsal segment, cat. Pal-fuchsine stain.

f. = terminating fibre.
d. = terminal disc.

C. B.=Body of cell of Clarke's column.

C. N.=Nucleus of cell of Clarke's column.

X.=Artificial defect or tear in the protoplasm of the cell body.

See text, p. 148 et seq.

Figure 18.—Longitudinal section through Clarke's column and the paracentral field; showing the richness of fine fibres in the paracentral field. 8th dorsal segment. Cat. Pal-fuchsine stain.

Cl.=Clarke's column.

PARC.=paracentral field.

See text, p. 148 et seq.

Plate IX.

Figures 19, 20, 21, 22.—Transections to show the position of the nucleus marginalis fossæ rhomboideæ (N. marg.) at various levels in the oblongata of the cat (Figures 19, 20, 21) and in man (Figure 22).

See text, p. 162 et seq.

Figure 23.—Two cells of the nucleus marginalis fossæ rhomboideæ.

See text, p. 163.

Figure 24.—Depicts the region around the distal part of the XX floor of the IV ventricle in a normal cat.

fl.=floor of IV ventricle.

N. XII.=nucleus of XII nerve.

N. X.=vago-glossopharyngeal nucleus.
=dorsal vagus nucleus.
=small celled vagus nucleus.

N. med.=nucleus of the medullary layer of the XII nucleus.
=nucleo intercalato (Staderini).

sol.=solitary bundle.
=respiratory bundle.
=trineural fascicle (Spitzka).
=descending root of the lateral mixed system.

N. homol. Cl.=nucleus homologue of Clarke's column.

N. marg.=nucleus marginalis fossæ rhomboideæ.

See text. p. 162 et seq.

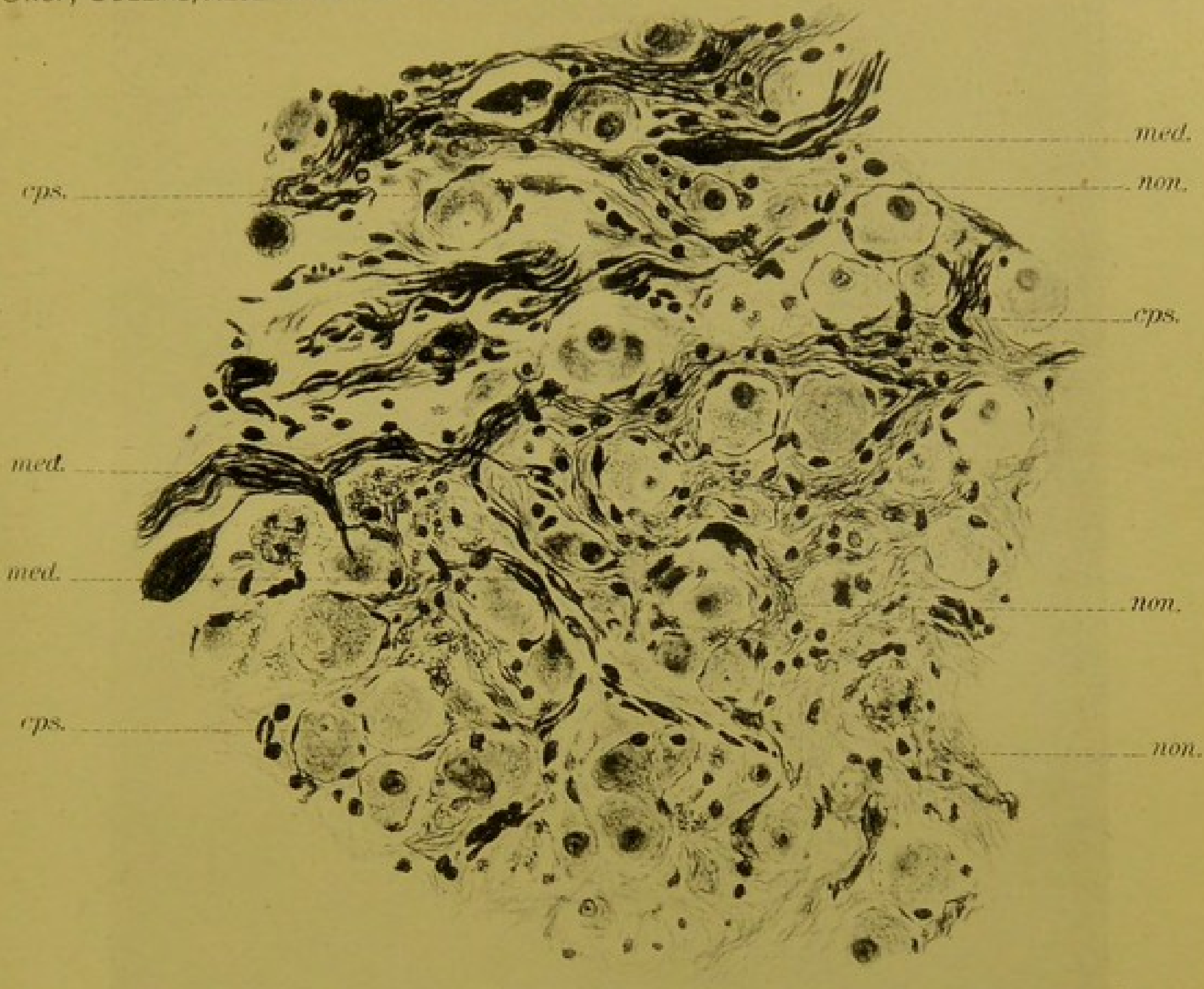
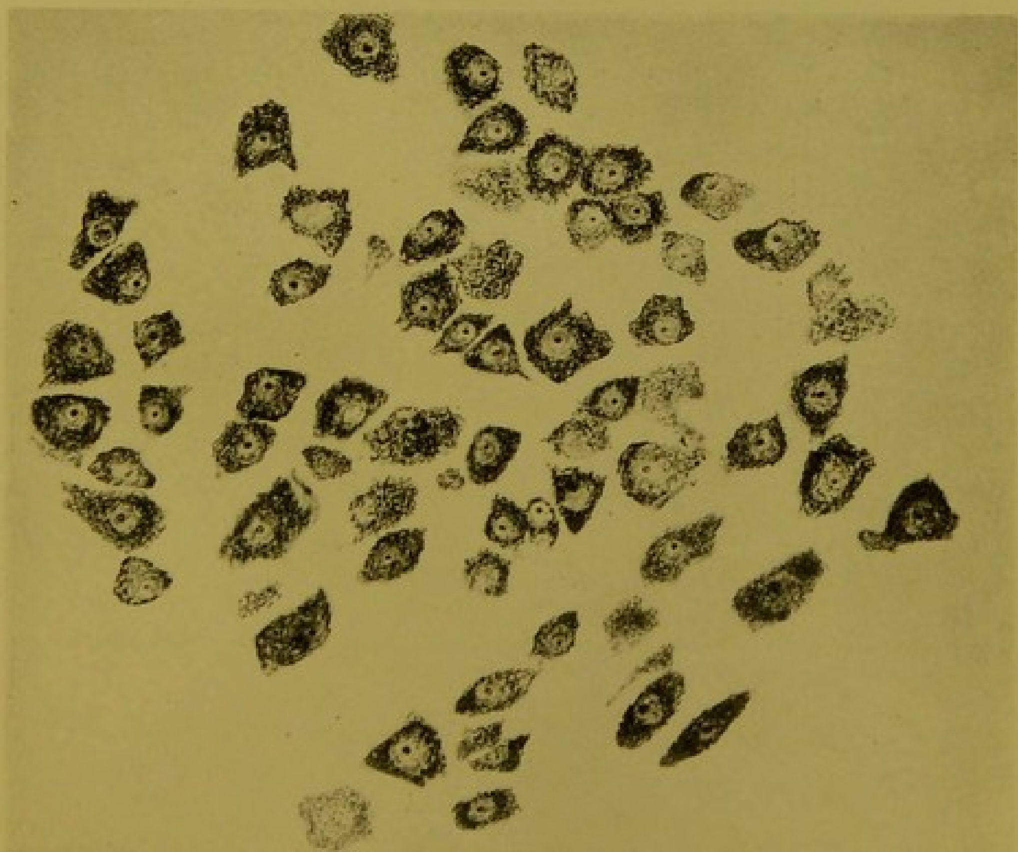


FIG. 1.



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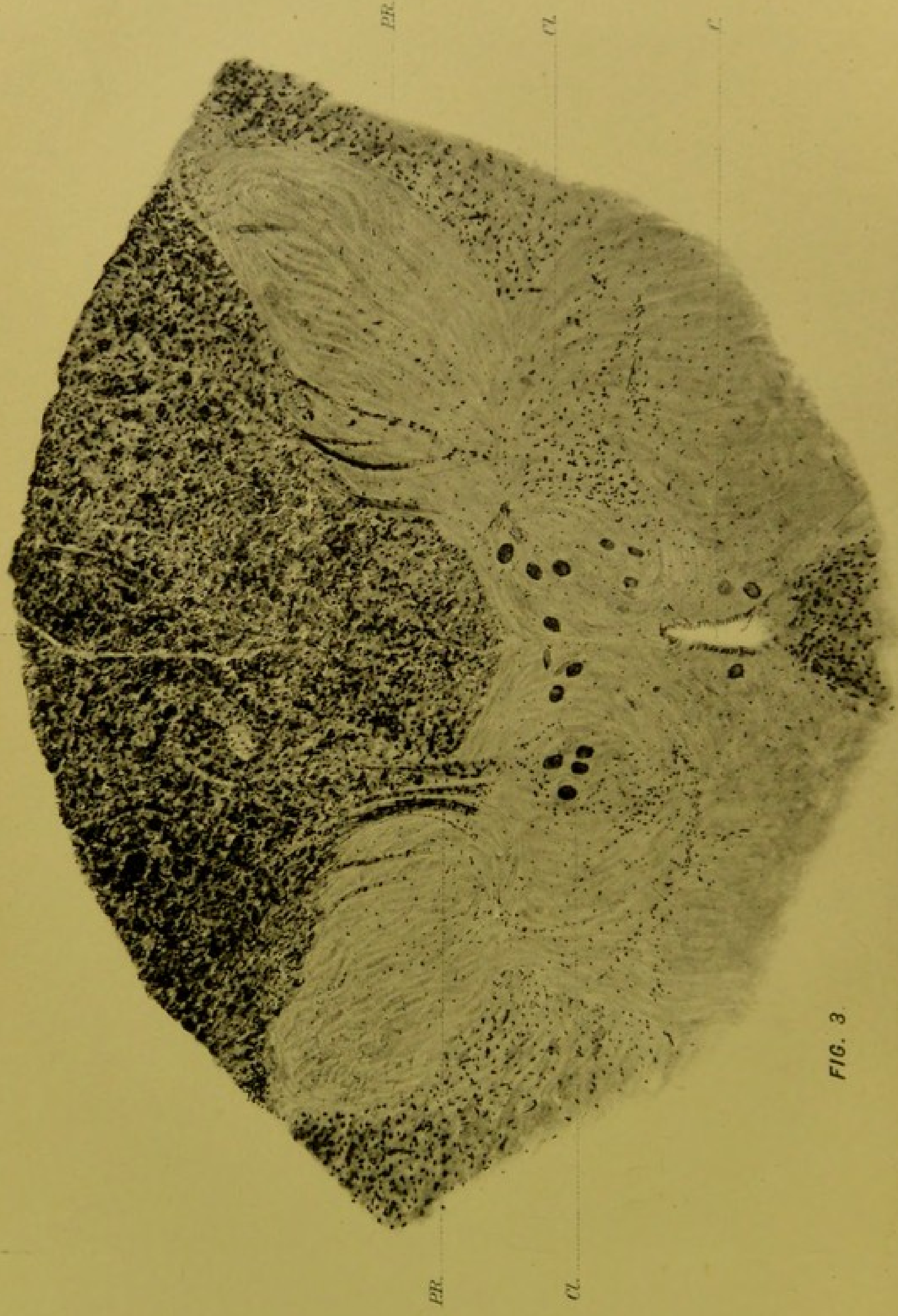

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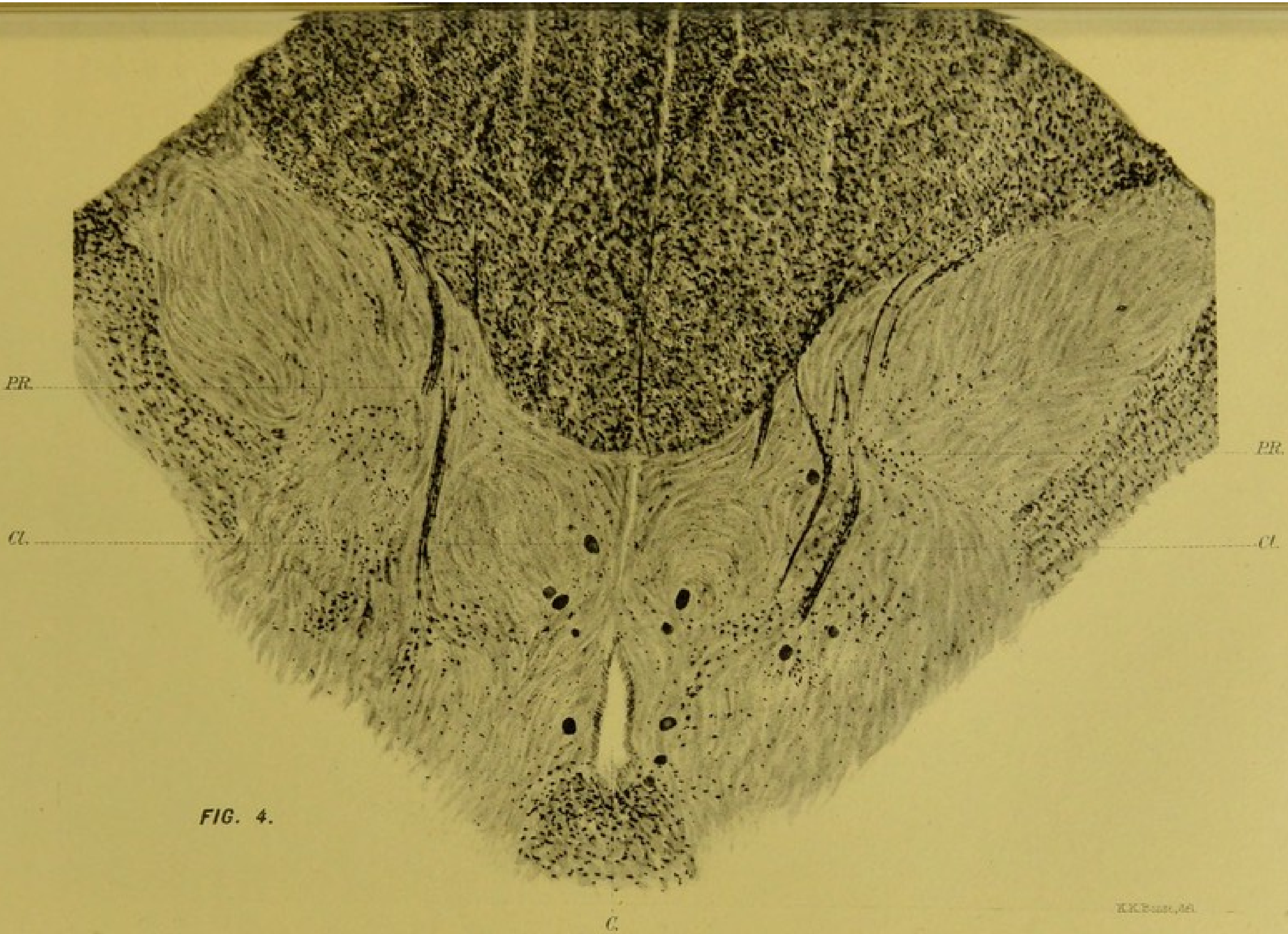

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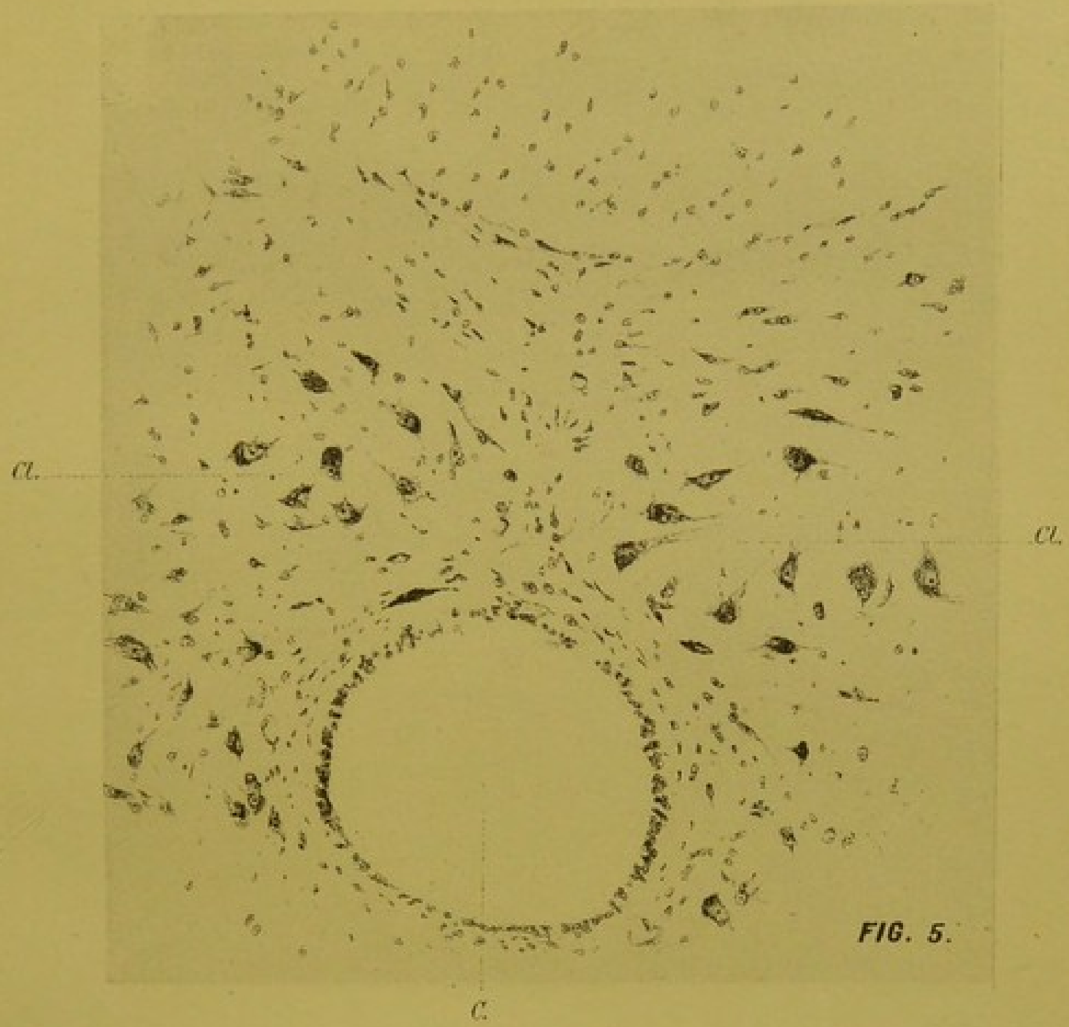

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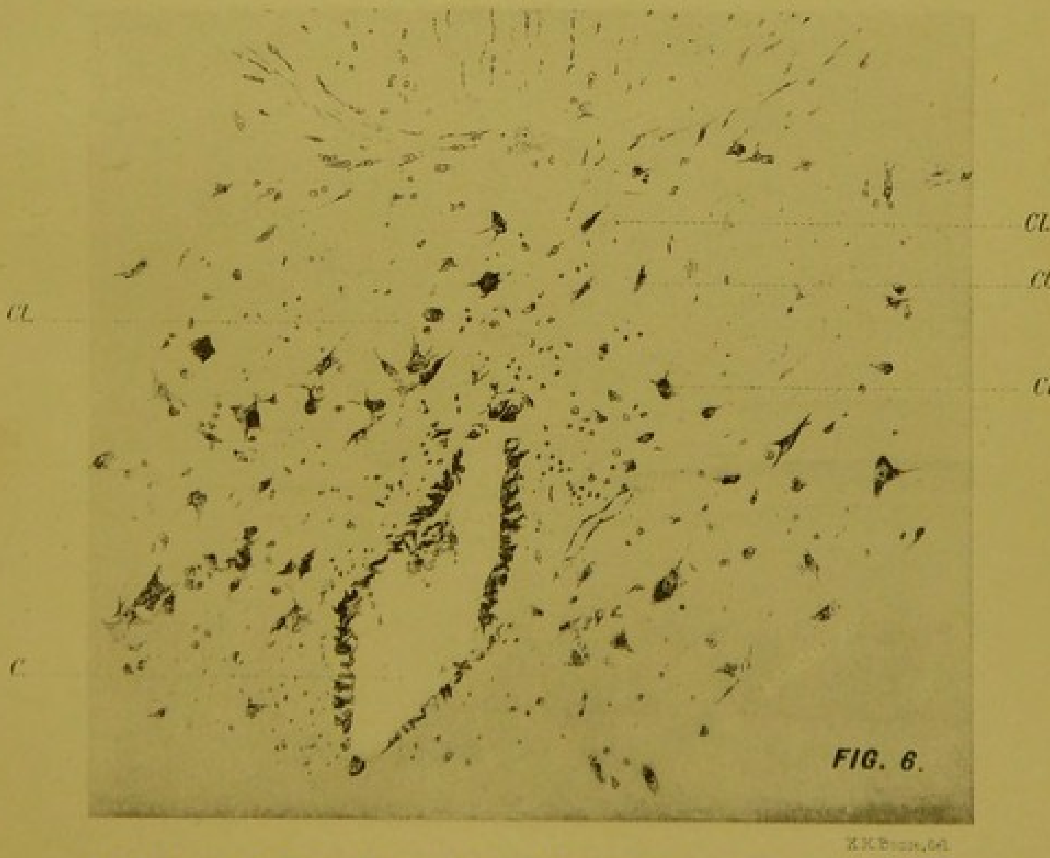

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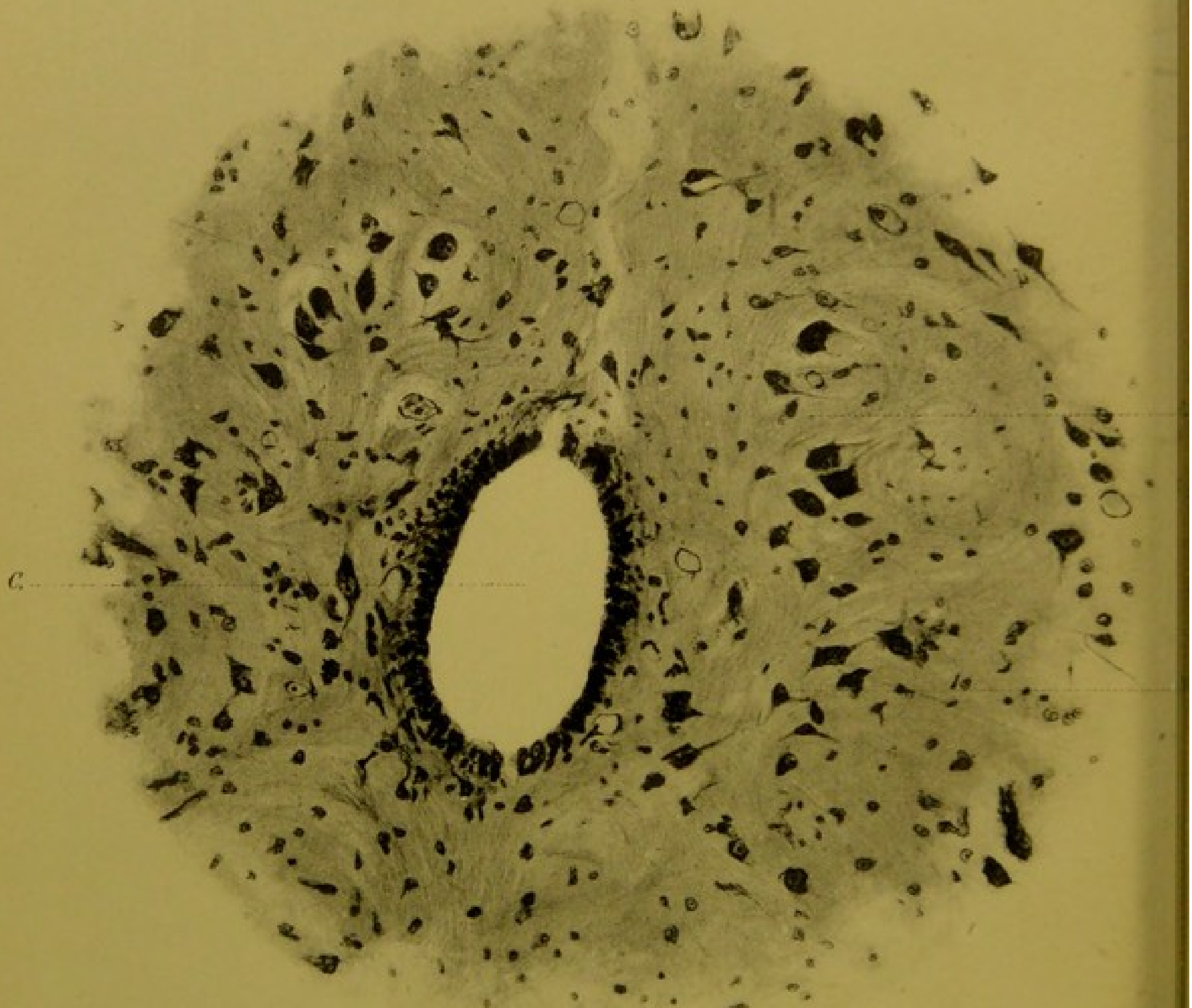

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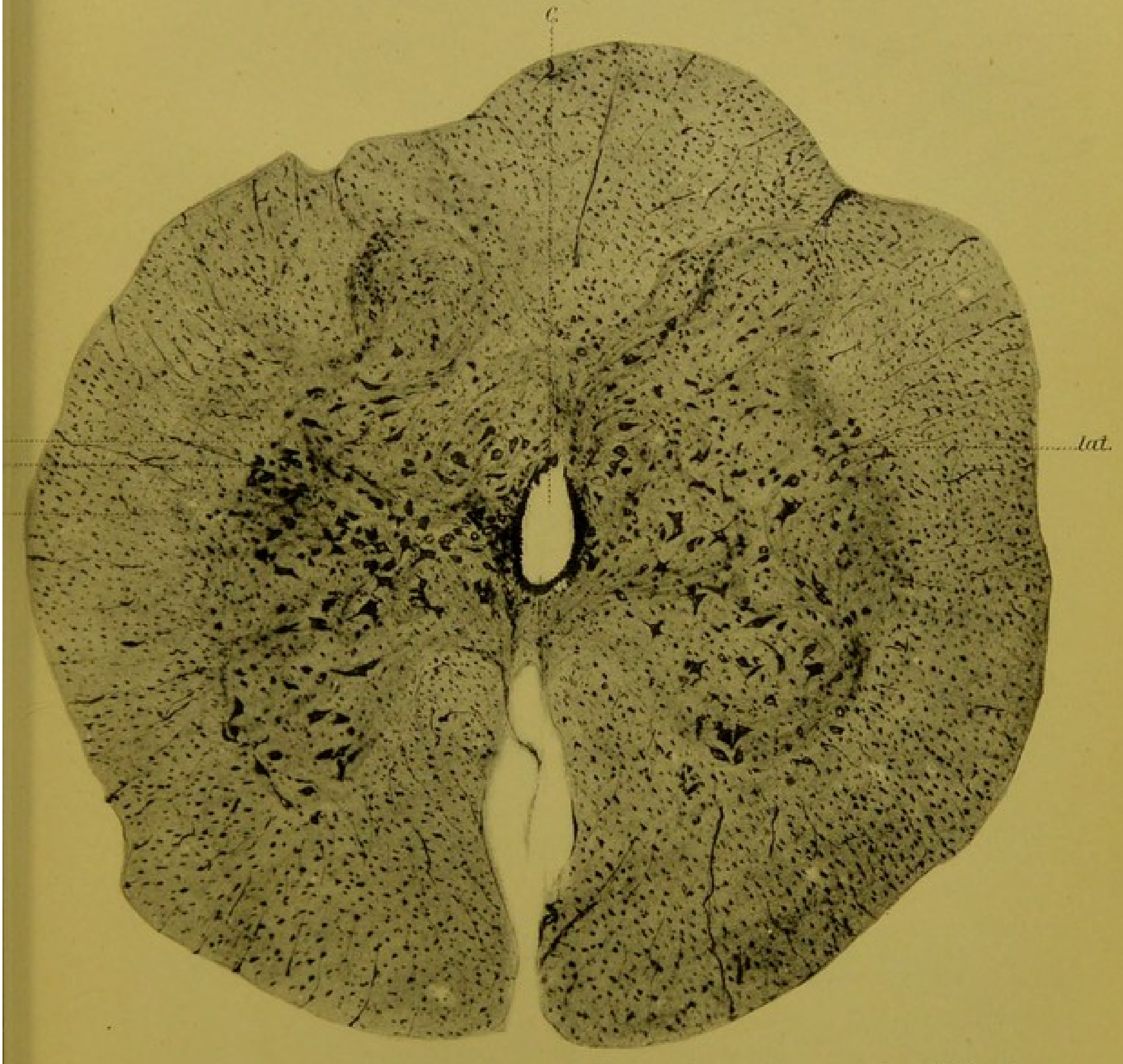

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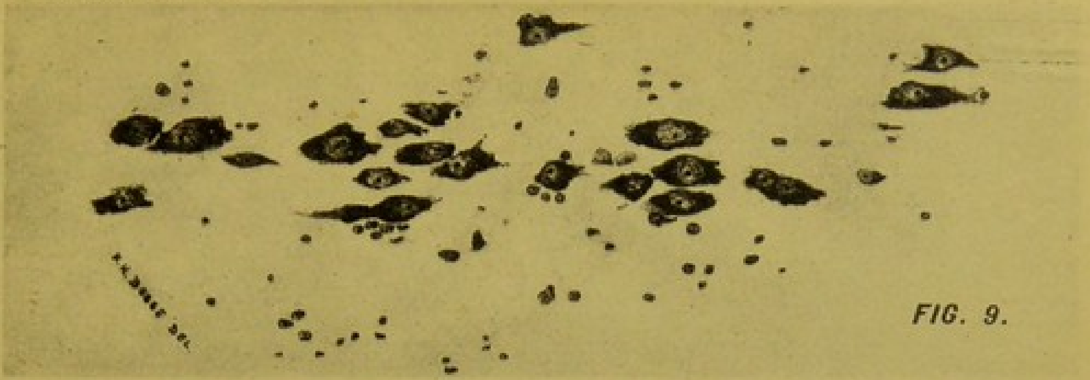

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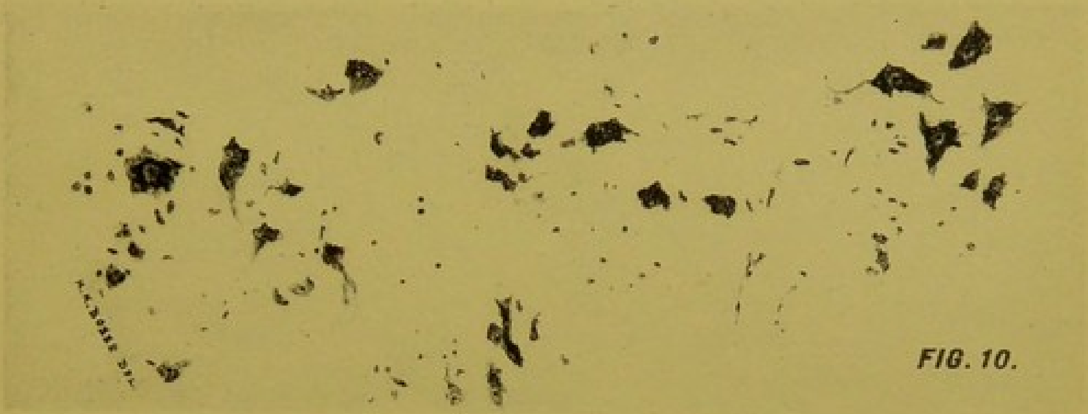

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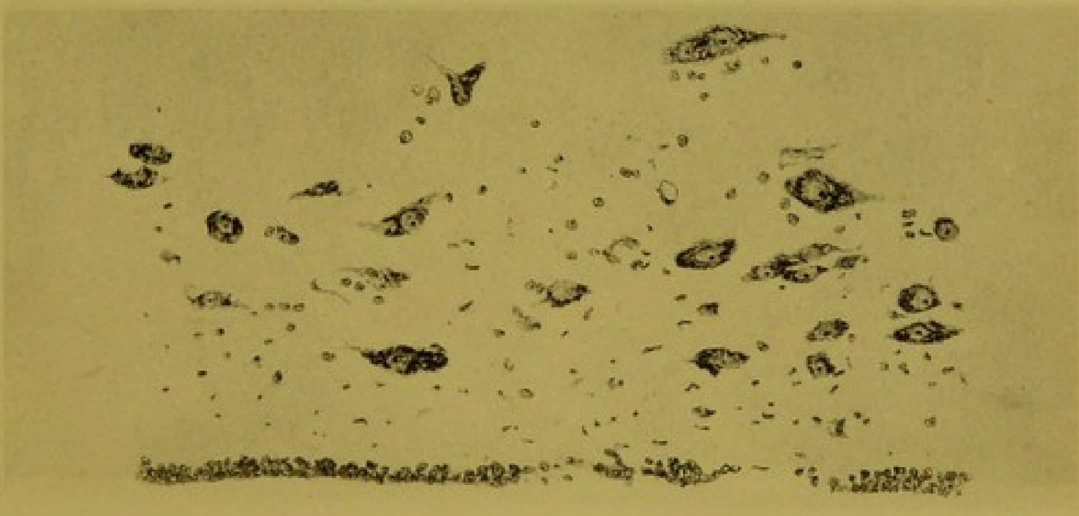

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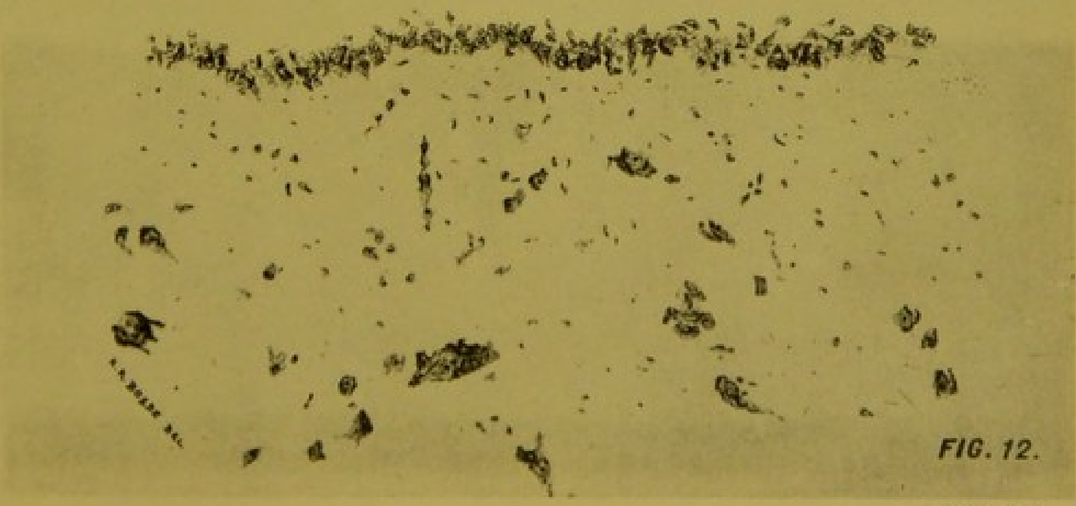

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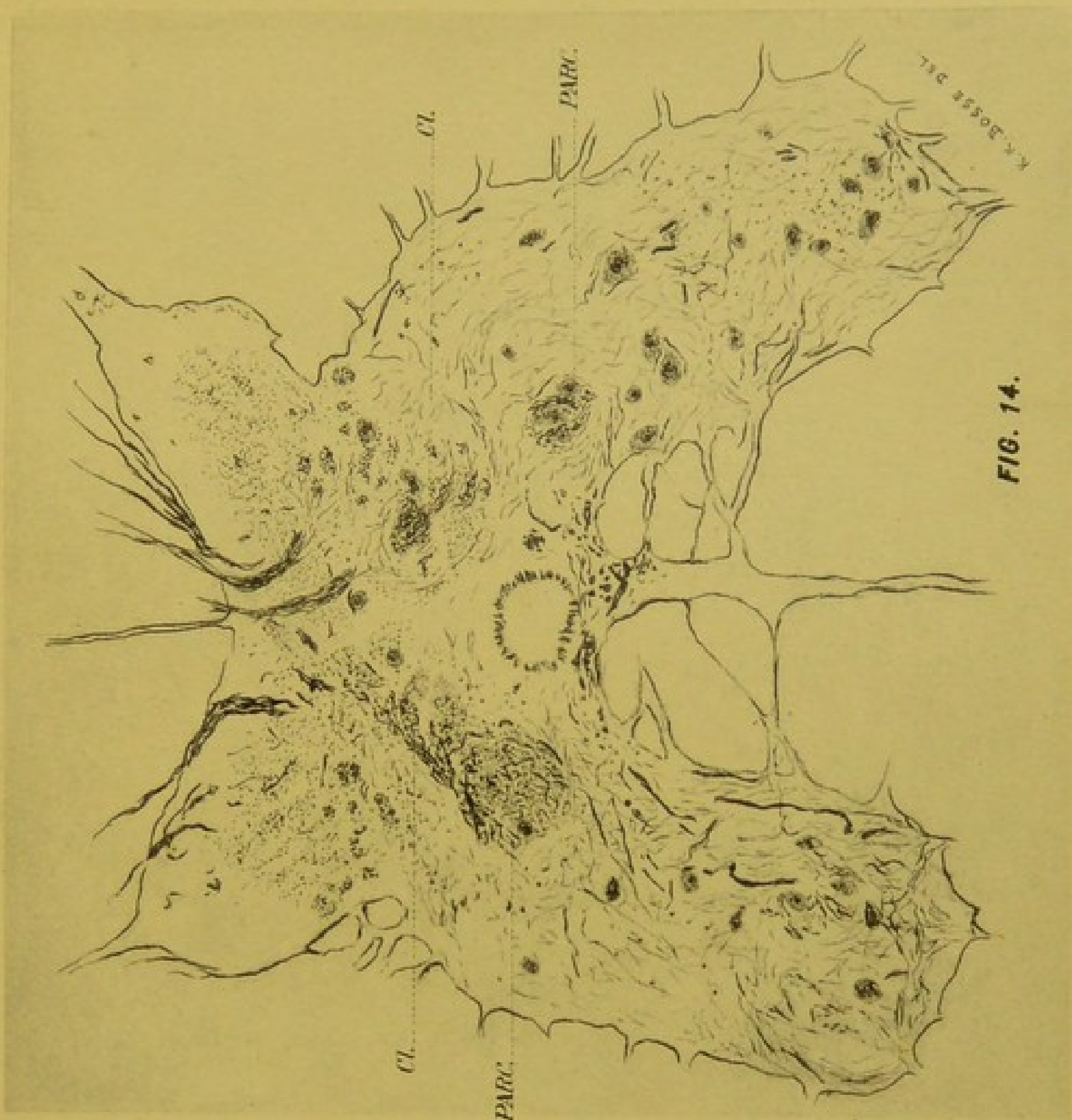

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FIG. 13.

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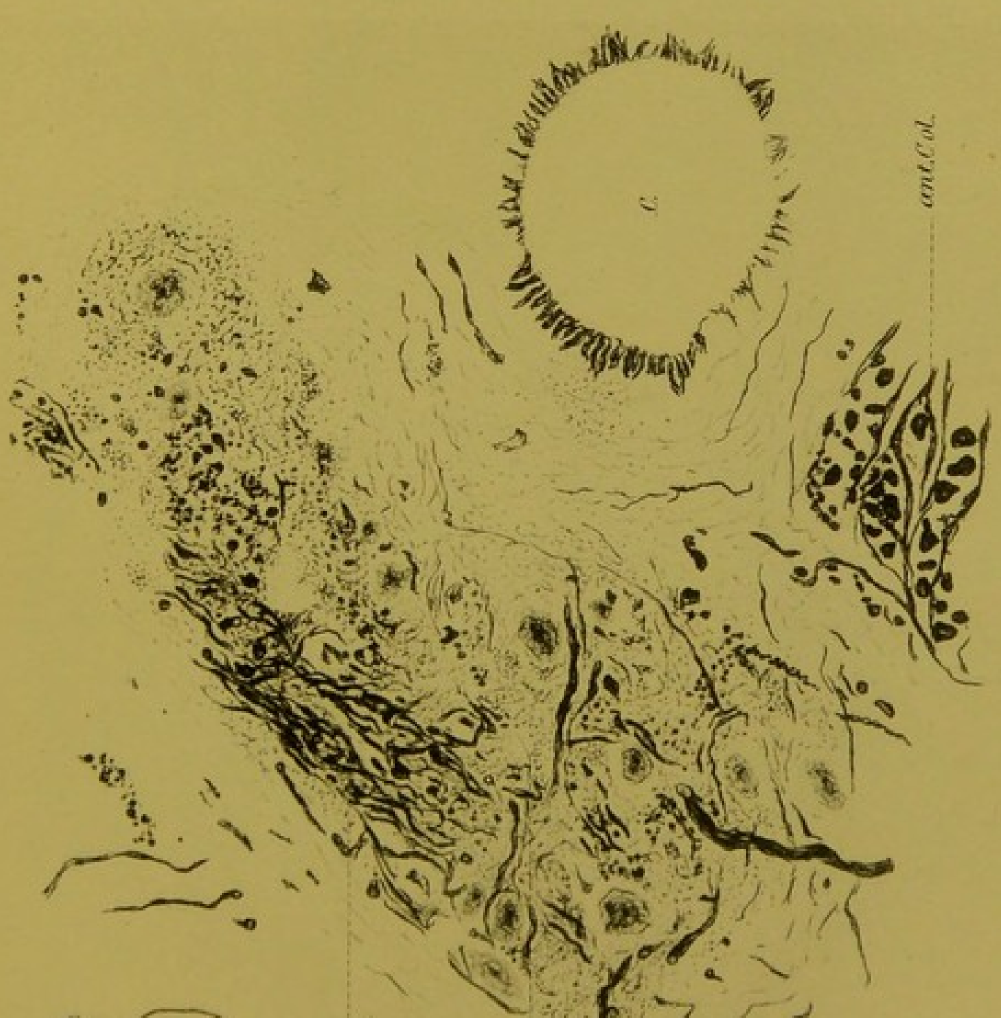

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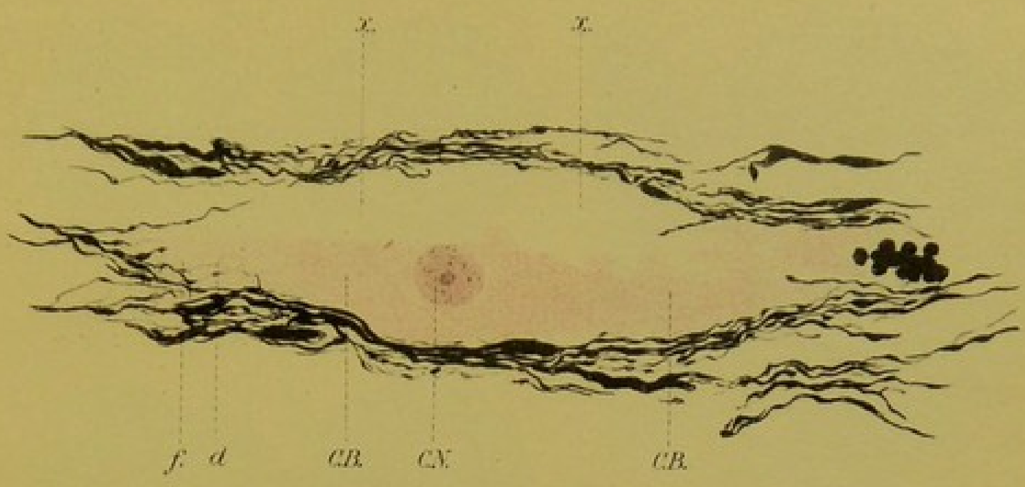

FIG. 17.

FIG. 18.

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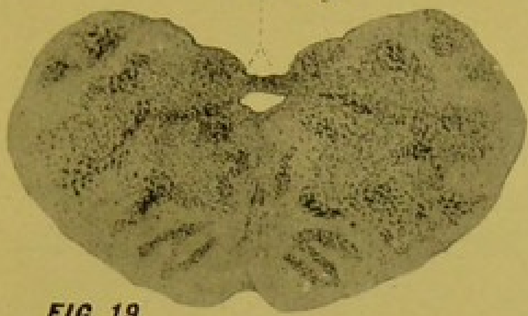

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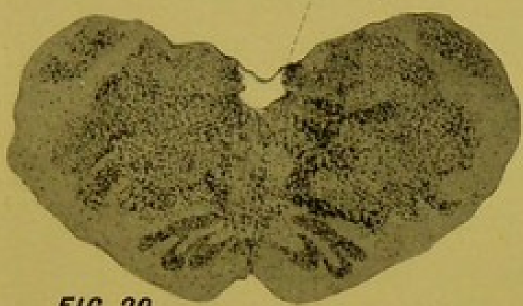

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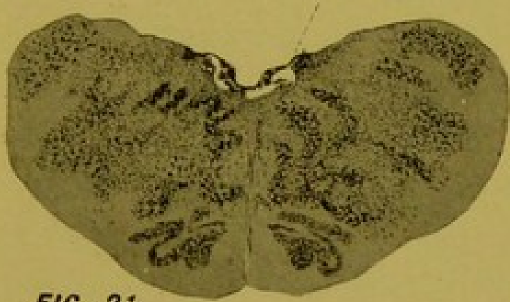

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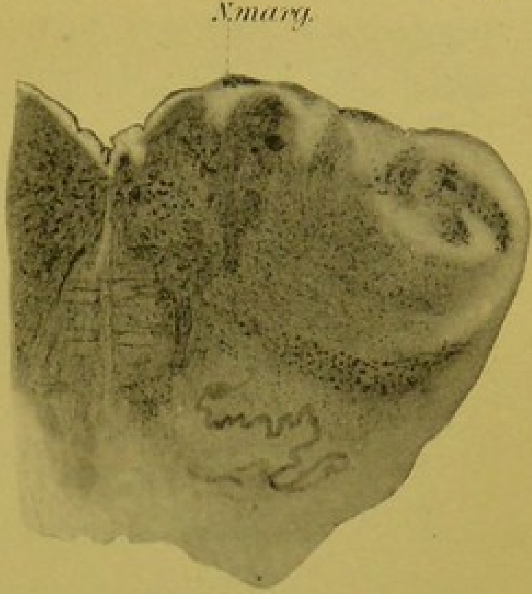

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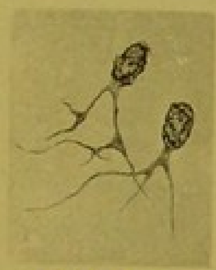

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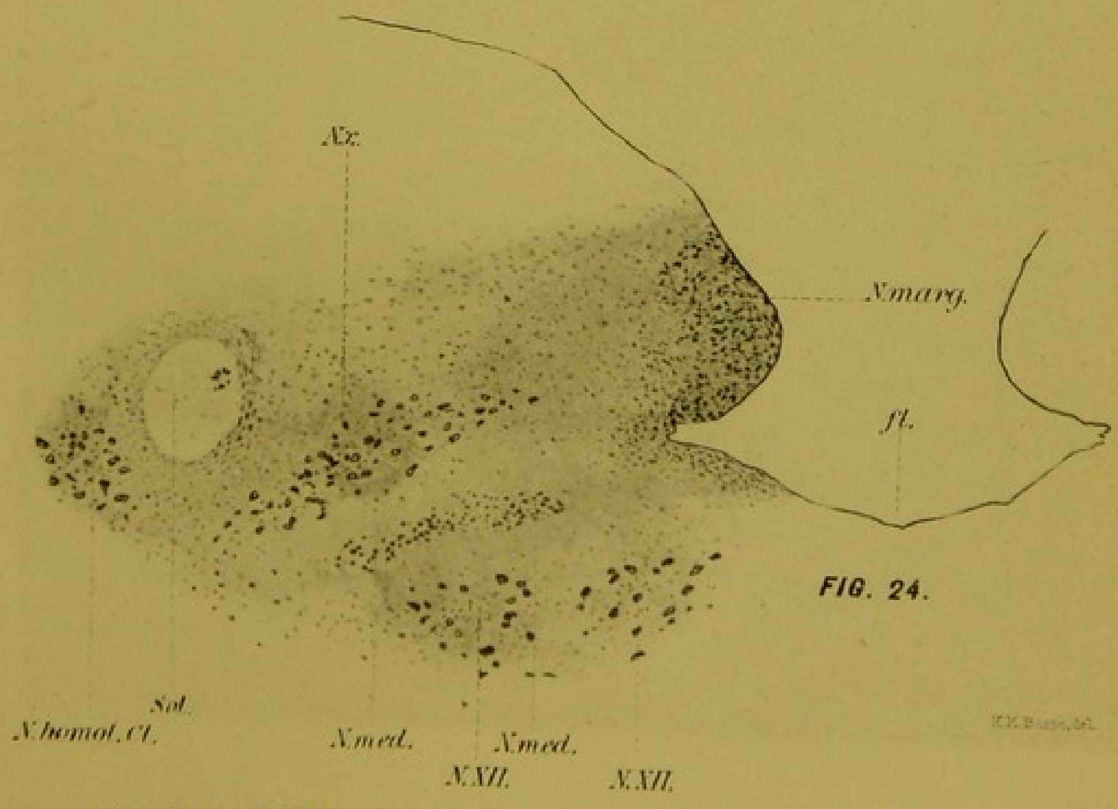

FIG. 24.

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FUNCTIONAL TOPOGRAPHY OF THE SYMPATHETIC NERVES AND THEIR CORRELATIONS IN THE CAT, AS ESTABLISHED ON THE GROUND OF PHYSIOLOGICAL EXPERIMENT.

BY B. ONUF (ONUFROWICZ), M. D.

[*From the Pathological Institute of the New York State Hospitals.*]

The subjoined topographical exposé and diagram of the functions of the sympathetic nerve and of its chief connections are intended as an appendix to the monograph by Dr. Joseph Collins and myself, preceding it in this volume and bearing the title, "Experimental researches on the central localization of the sympathetic with a critical review of its anatomy and physiology."

The accompanying tables and the diagram refer only to the spinal division of the sympathetic; the cranial division was left out from consideration because the topography of this part as based on physiological experiment is still but little known.

The purpose of the tables and diagram is to utilize the known physiological facts for the localization of lesions in the domain of the sympathetic nerves and their principal connections.

In arranging the subject it was thought best to begin with an enumeration of the functions of each communicant ramus, then to tabulate the physiological constitution of the sympathetic cords in their principal divisions (the cervical, thoracic, lumbar and sacral) and finally the constitution of the most important visceral nerves, such as the splanchnic, the mesenteric and the erigentes nerves.

The topography given in the tables and the diagram is such as results from a compilation of the physiological facts gained by various investigators, but chiefly Langley. An important drawback to this topography is that it does not relate to man, but predominantly to the cat. It may be said in extenuation, however, that while the large number of physiological facts noted in the cat gives a good basis to a topography of the functions of the sympathetic and its connections in this animal, such is by no means the case in man. In the human sympathetic system only very few facts have been established as to its functional topography.

I have mentioned that most of the results embodied in the accompanying diagram were the fruit of Langley's researches. This has also reference to the interruption of fibres by cells of sympathetic ganglia or plexuses, which interruptions this author proved by means of the nicotine method.

Regarding the diagram no further remarks seem necessary as the explanatory notes accompanying it give all the information desired.

It should be borne in mind that the subjoined exposé is only an appendix to the monograph above mentioned. It will be the more easily understood when read in connection with the latter.

I.

PHYSIOLOGICAL CONSTITUTION OF THE RAMI COMMUNICANTES OF CERVICAL NERVES.

According to Budge, Salkowski, Nawrocki and Przybylski, the pupil-dilating fibres of the cervical sympathetic nerve are derived in part from the 7th and 8th cervical nerves through their rami communicantes. Langley denies that any of the pupil-dilating fibres are derived from cervical nerves. He denies also that the latter give origin to vaso-constrictor and vaso-dilator fibres for the head. Otherwise nothing positive is known regarding the function of those fibres of the sympathetic which originate from cervical nerves.

II.

PHYSIOLOGICAL CONSTITUTION OF THE RAMI COMMUNICANTES DERIVED FROM THE DORSAL, LUMBAR AND SACRAL NERVES.

1st Dorsal: Chief nerve for dilatation of the pupil, for the nictitating membrane (3d lid) and for Müller's muscle.

A few accelerator fibres for the heart. Vaso-constrictor fibres for the blood vessels of the face. (Langley).

2d Dorsal: Dilator fibres for the pupil, motor fibres for the nictitating membrane and Müller's muscle.

(Aside from 3d dorsal) Chief accelerator nerve for the heart and chief vaso-constrictor nerve for the blood vessels of the head. (Langley).

Vaso-dilator fibres for the bucco-facial region. (Dastre and Morat).

Secretory (and trophic?) fibres for the sub-maxillary gland. (Langley).

3d Dorsal: Few dilator fibres for the pupil, few motor fibres to the nictitating membrane and Müller's muscle. (Langley).

(Aside from 2d dorsal) Chief accelerator nerve for the heart and chief constrictor nerve for the blood vessels of the head. (Langley).

Vaso-dilator fibres for the bucco-facial region. (Dastre and Morat).

Few secretory (and trophic?) fibres for the sub-maxillary gland. (Langley).

4th Dorsal: Few motor fibres for the nictitating membrane. (Langley).

Vaso-dilator fibres for the bucco-facial region. (Dastre and Morat).

Pilomotor fibres for the face and neck. (Langley).

Few accelerator fibres for the heart. (Langley).

Very few secretory fibres to the sub-maxillary gland. (Langley).

Vaso-constrictor, vaso-dilator and sweat secretory fibres for the fore paw. (Langley, Luchsinger, *et al.*)

5th Dorsal: A few (sometimes none) motor fibres to the nictitating membrane. (Langley).

Vaso-dilator fibres to the bucco-facial region. (Dastre and Morat).

Vaso-constrictor fibres for the ear. (Langley).

Pilomotor fibres for the face and neck. (Langley).

Very few secretory (and trophic?) fibres for the sub-maxillary gland. (Langley).

Very few, if any, accelerator fibres for the heart. (Langley).

Vaso-constrictor, vaso-dilator, and sweat secretory fibres for the fore paw. (Langley, Luchsinger, *et al.*)

Few vaso-constrictor fibres for the intestine. (Hallion and Fr. Frank).

6th Dorsal: Chief pilomotor nerve for the face and neck. (Langley).

Very few, if any, accelerator fibres for the heart. (Langley).

Vaso-constrictor, vaso-dilator, and sweat secretory fibres for the fore paw. (Langley, Luchsinger, *et al.*)

A few vaso-constrictor fibres for the intestine. (Hallion and Fr. Frank).

Vaso-constrictor and vaso-dilator fibres for the kidneys. (Bradford).

7th Dorsal: Vaso-constrictor, vaso-dilator, and sweat secretory fibres for the fore paw. (Langley, Luchsinger, *et al.*)

Pilomotor fibres for the face, neck and upper dorsal region. (Langley).

Few vaso-constrictor fibres for the intestine. (Hallion and Fr. Frank).

Vaso-constrictor and vaso-dilator fibres for the kidney. (Bradford).

8th, 9th and 10th Dorsal: Contain each:

Vaso-constrictor, vaso-dilator and sweat secretory fibres for the fore paw. (Langley, Luchsinger, *et al.*)

Pilomotor fibres to the region corresponding approximately to the area of distribution of the somatic sensory fibres of the three nerves. (Langley).

Vaso-constrictor fibres for the intestine. (Hallion and Fr. Frank). Largest representation in the 10th dorsal.

Vaso-constrictor and vaso-dilator fibres for the kidney. (Bradford).

11th Dorsal: Pilomotor fibres to a region corresponding approximately to the area of distribution of the sensory somatic fibres of the nerve. (Langley).

Vaso-constrictor and vaso-dilator fibres for the intestine. (Hallion and Fr. Frank).

Large vaso-constrictor and vaso-dilator nerve for the kidney. (Bradford).

Few (sometimes none) sweat secretory fibres for the hind paw. (Luchsinger).

12th and 13th Dorsal: Each contain pilomotor fibres to the region corresponding approximately to the area of distribution of the somatic sensory fibres of the two nerves. (Langley).

Vaso-constrictor and vaso-dilator fibres for the intestine. (Hallion and Fr. Frank).

Large vaso-constrictor and vaso-dilator nerve for the kidney. (Bradford).

Vaso-constrictor, vaso-dilator and sweat secretory fibres for the hind paw. (Luchsinger, Langley, *et al.*)

1st Lumbar: Pilomotor fibres to the region corresponding approximately to the area of distribution of the somatic sensory fibres of the nerve.

A few vaso-constrictor and vaso-dilator fibres for the intestine. (Hallion and Fr. Frank).

Few vaso-constrictor and vaso-dilator fibres for the kidney. (Bradford).

Vaso-constrictor, vaso-dilator and chiefly sweat secretory fibres for the hind paw. (Luchsinger, Langley, *et al.*)

Rather few vaso-constrictor fibres for the tail. (Langley).

2d Lumbar: Pilomotor fibres to the region corresponding approximately to the area of distribution of the somatic sensory fibres of the nerve. (Langley).

Vaso-constrictor, vaso-dilator and (chiefly) sweat secretory fibres for the hind paw. (Langley, Luchsinger, *et al.*)

Vaso-constrictor fibres for the arteries of the tail. (Langley).

Few vaso-constrictor and vaso-dilator fibres for the kidney. (Bradford).

Vaso-constrictor and vaso-dilator fibres for the intestine. (Hallion and Fr. Frank).

Vaso-constrictor and viscero-inhibitory fibres to the blood vessels and muscles of the lower intestine. (Langley).

Motor and vaso-constrictor fibres to nonstriate muscles and blood vessels of the skin surrounding the anus.

Motor and vaso-constrictor fibres for nonstriate muscles and arteries of the internal sexual organs: Tubes, uterus, vagina, vas deferens, vesicula seminalis. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and for blood vessels of the external sexual organs: Penis, scrotum, vulva. (Langley).

Few (if any) motor fibres for nonstriate muscles (detrusor) of the bladder. (Langley).

3d Lumbar: Pilomotor fibres to the region corresponding approximately to the area of distribution of the somatic sensory fibres of the nerve. (Langley).

Vaso-constrictor, vaso-dilator and sweat secretory fibres for the hind paw (Langley, Luchsinger, *et al.*)

Large vaso-constrictor nerve for the arteries of the tail. (Langley).

A few vaso-constrictor and vaso-dilator fibres for the kidney. (Bradford).

Viscero-inhibitory and vaso-constrictor fibres to the muscles and blood vessels of the lower intestine. (Langley).

Motor and vaso-constrictor fibres to nonstriate muscles and blood vessels of the skin around the anus. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and arteries of the internal sexual organs: Tubes, uterus, vagina, vas deferens, vesicula seminalis. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and blood vessels of the external sexual organs: Penis, scrotum, vulva. (Langley).

Motor fibres for nonstriate muscles (detrusor) of the bladder. (Langley and others).

4th Lumbar: Inconstant pilomotor nerve. If present, its area of distribution corresponds approximately to that of the sensory somatic fibres of the nerve. (Langley).

Few sweat fibres for the hind paw. (Luchsinger).

Large vaso-constrictor nerve for the arteries of the tail. (Langley).

Few vaso-constrictor and vaso-dilator fibres for the kidney. (Bradford).

Viscero-inhibitory and vaso-constrictor fibres for nonstriate muscles and blood vessels of the lower intestine. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and blood vessels of the skin surrounding the anus. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and arteries of the internal sexual organs: Tubes, uterus, vagina, vas deferens, vesicula seminalis. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and blood vessels of the external sexual organs: Penis, scrotum, vulva. (Langley).

Large motor nerve for nonstriate muscles (detrusor) of the bladder. (Langley and others).

5th Lumbar: Viscero-inhibitory and vaso-constrictor fibres for the muscles and blood vessels of the lower intestine. (Langley).

Motor and vaso-constrictor fibres to nonstriate muscles and blood vessels of the skin surrounding the anus. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and arteries of the internal sexual organs: Tubes, uterus, vagina, vas deferens, vesicula seminalis. (Langley).

Motor and vaso-constrictor fibres for nonstriate muscles and blood vessels of the external sexual organs: Penis, scrotum, vulva. (Langley).

Large motor nerve for nonstriate muscles (detrusor) of the bladder. (Langley).

6th Lumbar, *7th Lumbar*, *1st Sacral:* According to Langley the communicating branches from these nerves are not concerned in innervation of the viscera. What other functions they may have is not known.

2d Sacral, *3d Sacral*, *4th Sacral:*

Viscero-motor and vaso-dilator fibres for the lower intestine. Motor fibres for the bladder. Viscero-motor and vaso-dilator fibres for the external sexual organs.	Via nervi erigentes.

Viscero-inhibitory fibres for the skin surrounding the anus. (From sacral nerves directly to the hypogastric plexus).

5th Sacral, *Coccygeal Nerve:* Nothing definite known.

PHYSIOLOGICAL CONSTITUTION OF THE TWO SYMPATHETIC CORDS.

1.—*Cervical Sympathetic Nerve:* According to physiological research, the cervical sympathetic nerve is composed as follows:

Fibres, the section of which causes diabetes.

Secretory fibres to the lachrymal gland.

Secretory fibres to the sweat glands of the head.

Secretory fibres to the submaxillary gland.

Trophic fibres to the parotid and submaxillary glands.

Vasomotor and vaso-dilator fibres to the blood vessels of the brain.

Viscero-motor fibres to the nictitating membrane and to Müller's muscle. Pupil-dilating and probably pupil-contracting fibres. Vaso-constrictor and vaso-dilator fibres to the bucco-facial region. Trophic fibres for the skin and bones of the head. Pilomotor fibres to the head and to the back of the neck. (Through the 2nd cervical nerve) vaso-constrictor fibres to the blood vessels of the ear.	From rami communicantes of dorsal nerves via stellate ganglion.

2.—*Thoracic Sympathetic Nerve:* The upper part of the thoracic sympathetic nerve from the 5th, 6th or 7th thoracic ganglion up to the stellate ganglion contains:

(*a*) All those fibres from the rami communicantes of upper dorsal nerves which after passing through the stellate ganglion become part of the cervical sympathetic nerve. (See the latter—compare with the diagram).

(*b*) Accelerator fibres for the heart passing to the latter by way of the stellate ganglion (and of the cardiac nerves).

(*c*) Vaso-constrictor, vaso-dilator and sweat secretory fibres for the fore paw, reaching the latter by passing through the stellate ganglion and then joining the brachial plexus.

The lower part of the thoracic sympathetic from the 5th, 6th or 7th thoracic ganglion downward, is composed of:

(*d*) Pilomotor fibres supplying (together with those of the lumbar sympathetic nerve) the skin from the level of the 6th, 7th or 8th dorsal vertebra, down to the end of the tail, which area comprises also the skin of the fore and hind paws.

(*e*) Vasomotor, vaso-dilator and sweat secretory fibres for the fore paw (from the 10th thoracic ganglion upwards —reaching the fore paw on the same pathway as those mentioned under (*c*)—and for the hind paw (from the 11th thoracic ganglion downwards) via sciatic nerve.

3.—*Lumbar Sympathetic Nerve:* The lumbar sympathetic nerve contains:

Vasomotor, vaso-dilator and sweat secretory fibres for the hind paw.

Pilomotor fibres, supplying (together with those of the thoracic sympathetic nerve) the skin from the level of the 6th, 7th or 8th dorsal vertebra, down to the end of the tail, which area comprises also the skin of the fore and hind paw.

Vaso-constrictor fibres to the arteries of the tail.

Vaso-constrictor and viscero-motor fibres to blood vessels and nonstriate muscles of the skin surrounding the anus.

Vaso-constrictor and viscero-inhibitory fibres to the lower intestine.

Vaso-constrictor and vaso-dilator fibres to the upper intestine.

Vaso-constrictor and vaso-dilator fibres to the kidney.

Viscero-motor fibres to the bladder.

Viscero-motor and vaso-constrictor fibres to the internal sexual organs.

Viscero-motor and vaso-constrictor fibres to the external sexual organs.

4.—*Sacral Sympathetic Nerve:* The sacral sympathetic nerve is composed of:

Vaso-constrictor, vaso-dilator and sweat secretory fibres for the hind paw. (?)

Vaso-constrictor fibres to the arteries of the tail.

Viscero-motor, viscero-inhibitory and vaso-constrictor fibres (by way of the sacral nerves) to blood vessels and nonstriate muscles of the skin surrounding the anus.

Viscero-motor and vaso-dilator fibres to the lower intestine.

Viscero-motor fibres to the bladder.

Viscero-motor and vaso-dilator fibres to the external sexual organs.

PHYSIOLOGICAL CONSTITUTION OF THE SPLANCHNIC, MESENTERIC AND ERIGENTES NERVES.

1.—*Splanchnic Nerves:* Into the composition of the splanchnic nerves the following kinds of fibres enter:

Vaso-constrictor, vaso-dilator, secretory and viscero-inhibitory fibres to the blood vessels, glands and non-striate muscles of the stomach.

Vaso-constrictor, vaso-dilator and viscero-inhibitory fibres to the upper intestine.

Secretory, vaso-constrictor and viscero-motor fibres to the liver and blood vessels and muscles of the gall ducts.

Vaso-constrictor, secretory and trophic fibres to the pancreas.

Vaso-constrictor and vaso-dilator fibres to the kidney.

2.—*Mesenteric Nerves:* (Superior, medius, inferior). The mesenteric nerves are said to contain:

Vaso-constrictor and viscero-inhibitoty fibres to the lower intestine.

Viscero-motor fibres to the bladder.

Vaso-constrictor and viscero-motor fibres to the internal sexual organs.

Vaso-constrictor and viscero-motor fibres to the external sexual organs.

3.—*Nervi Erigentes:* The nervi erigentes are constituted of:

Viscero-motor and vaso-dilator fibres to the lower intestine.

Viscero-motor fibres to the bladder.

Viscero-motor and vaso-dilator fibres for the external sexual organs.

PLATE I.

Diagram to show the origin, course and Function of the fibres of the sympathetic nerve as found by physiological experiment: mainly in the cat.