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## Surgery of the autonomic nervous system

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SURGERY

of the

AUTONOMIC NERVOUS SYSTEM.

UNI. of NEBR.  
COLLEGE of MEDICINE.

GUY R. McCUTCHEON.

## SURGERY OF THE AUTONOMIC NERVOUS SYSTEM.

The great volume of anatomical and physiological research that has been directed toward the autonomic nervous system during the past few years has been responsible for an almost equal amount of attempted clinical application in the form of surgery.

The results of these attempts have indeed been variable; from most illuminating successes to utter failures. Far too many operations upon the autonomic nervous system have been undertaken on a purely empirical basis. Theories have often overshadowed facts, but even so, there is gradually crystallizing a knowledge of the sympathetic nervous system that is certain to remove this branch of surgery from the category of surgical curiosities to a position among definitely indicated, rational procedures.

My purpose in selecting so technical a subject does not include a desire to even point out, much less discuss, all of the controversies and contradictions that have been so detrimental to the progress of this new field, nor do I intend to speculate, but merely to point out some of the things that are known, and to indicate the striking results that follow a proper application of these facts.

Despite the manifest widespread interest in this new and rapidly developing subject it is my belief that relatively few individuals are possessed of a comprehensive understanding of it. Such an understanding is not easily obtained and this effort has not been without disappointments but it is hoped that it will reveal the present status of surgery of the autonomic nervous system.

The phrase "Autonomic Nervous System" is employed in a general way, as Ranson, Kuntz and Adson have used it, to designate that functional division of the sympathetic nervous system which supplies the glands, heart and smooth muscle with their efferent innervation, this includes the craniosacral as well as the thoracico-lumbar division of the sympathetic nervous system -- an explanation of the latter two divisions will be undertaken later.

Sympathectomy is defined as the surgical removal of a part of a sympathetic nerve. Periarterial sympathectomy is the removal of the adventitia from an artery supposedly denuding a given artery of its sympathetic nerve supply -- this may also be referred to as arterial decortication. There will be occasion to use these terms frequently.

Sympathetic ganglionectomy, ramisectomy, and trunk resection is a newer term that describes a newer operation i.e. extirpation of one or more sympathetic ganglia, severance of all rami communicantes and resection of that portion of the trunk which is in immediate relation with the ganglia removed. This procedure is called either cervical, thoracic, or lumbar ganglionectomy, ramisectomy and trunk resection, depending on which portion of the trunk is operated upon.

The anatomy of the sympathetic nervous system is entirely too complicated for a lengthy presentation in this paper but it is necessary to give a brief summary of it, with special reference to certain important facts.

In general the sympathetic nervous system is an aggregation of ganglia, plexuses, and nerve fibers which supply the glands, heart, and smooth muscle. Their most abundant distribution is in the cranial vault and neck, the thoracic and abdominal cavities.<sup>1 and 2.</sup>

The sympathetic trunks are arranged in linear order and lie along the ventrolateral aspects of the vertebral column. They extend from the base of the skull to the coccyx. Each sympathetic trunk is made up of a series of twenty-one or twenty-two ganglia, connected by longitudinal fibers. The ganglia are segmentally distributed except in the cervical region where there are only three viz. the superior cervical sympathetic ganglia--middle cervical sympathetic ganglia (frequently absent) and the inferior sympathetic ganglia.

The ganglia are connected with the spinal nerves thru communicating rami. Gray rami communicantes are fibers from the sympathetic trunk which connect the sympathetics with every spinal nerve on the same side only. White rami are only given off in the thoracic and upper lumbar regions. They contain visceral afferent & preganglionic visceral efferent fibers which go from the central nervous system to the sympathetic trunk. The visceral afferent fibers merely pass through the sympathetic trunk to the viscera while the preganglionic visceral efferent fiber ends in synaptic relation with a postganglionic neuron in the sympathetic ganglia. White rami contain only fibers of the sympathetic nervous system.<sup>1 and 6.</sup>

There are three streams of preganglionic fibers which leave the cerebrospinal axis; the cranial stream, the thoracico lumbar stream, and the sacral stream. The fibers of the cranial and sacral streams make no connexion with the sympathetic trunk but run directly to the sympathetic nerve plexuses, but, the fibers of the thoracico-lumbar stream running in the white rami join the sympathetic trunk and terminate in the ganglia of the trunk. The cranial and sacral streams end in the terminal ganglia.<sup>1</sup> It is obvious that the distribution of the cranial and sacral groups is similar while that of the thoracic and lumbar streams is also similar but distinctly different than the craniosacral. It has also been noted that the response of the cranial and sacral divisions to drugs such as atropin and adrenalin is similar and opposite to the reaction of the thoracico-lumbar group. Therefore the cranial and sacral divisions have been grouped together and called the parasympathetic system while the thoracico-lumbar group is termed the sympathetic nervous system.

The functional relationship of these two systems is very important. This paper will deal almost entirely with the sympathetic division of the autonomic nervous system.

One other fact is essential to a fundamental concept of the general sympathetic visceral efferent innervation -- there are always two and only two nerve fibers necessary for conduction of an impulse from the central nervous system to a gland or smooth muscle. They are a preganglionic and a postganglionic fiber.<sup>1.</sup>

Much of the material that is to follow is directly dependant upon the sympathetic nerve supply to arteries so that this will be described in some detail.

Recent experimentation has proven beyond all doubt that arteries of the extremities receive their sympathetic innervation from adjacent spinal nerves at intervals throughout the length of their course.<sup>2</sup> No large longitudinal bundle of fibers extending from the periarterial plexuses along the course of the artery can be demonstrated as was formerly believed to exist.<sup>2 and 29</sup>

It is assumed though not proven that the sympathetic nerve supply to an artery contains both vasoconstrictor and vasodilatator fibers. The aorta, vertebral and carotid arteries are supplied by plexuses. Arteries of the extremities are supplied by fibers that are mediated from the thoracico-lumbar division of the sympathetic trunk. These fibers are distributed by the corresponding peripheral nerve as a vasomotor component and gives off its vasoconstrictor fibers to the adjacent artery.<sup>2</sup>

The vasoconstrictor fibers for the upper extremity are derived largely from the stellate ganglion (fusion of Inf. Cerv. & First Thoracic Gang.) some from the middle cervical ganglion and sometimes there are branches from the brachial plexus and the second thoracic ganglion. The lower extremity is largely supplied by the fourth and fifth lumbar and first sacral but some are derived from the second and third sacral ganglia.<sup>2</sup>

*Symp. Nerves of Large Intestines.* The descending portion of the colon and the upper portion of the rectum are supplied by fibers from the inferior mesenteric plexus which is the derivative of the aortic plexus and therefore contains both parasympathetic and sympathetic elements. The lower part of the rectum is supplied by fibers derived from the white rami of the second, third and fourth lumbar nerves<sup>2</sup> whose fibers are ultimately distributed to the circular muscles by way of the hypogastric and pelvic plexuses.<sup>3</sup> The sympathetic fibers cause dilatation of the circular muscles of the intestine while the parasympathetic nerves cause contraction. The importance of these facts will become evident later.<sup>3</sup>

The nerve supply to the heart was a matter of considerable argument until recently and all men are not yet agreed as to details. However, there is a great deal of clinical and experimental evidence of the existence of accelerator cardiac nerves arising from thoracic segments of the sympathetic cord.<sup>4</sup> It was formerly thought that all cardiac accelerator or sympathetic fibers were mediated through the middle and inferior cervical sympathetic ganglia. In a recent study by Kuntz on fetuses and adult cadavers accelerator fibers to the heart were traced from the second and third thoracic sympathetic ganglia in all cases and sometimes a branch from the fourth thoracic ganglia joins the deep cardiac plexus posterior to the aorta. Stimulation of any of any of these fibers results in acceleration of the heart rate so it is obvious that reflex cardiac acceleration will not be abolished even after cervical sympathetic ganglionectomy. All of these fibers are postganglionic or white rami arising from ganglia of the sympathetic trunk. The corresponding preganglionic fibers are components of the upper thoracic

nerves down to and including the fifth. These fibers go via the annulus of Vieussens to the inferior cervical ganglion.<sup>5</sup>

The sensory or afferent nerve supply of the heart is not well understood. There are sensory fibers for the heart which reach the sympathetic nervous system through the white rami of the upper three thoracic ganglia and the vagus on the left side.<sup>6</sup> However, removal of the left superior cervical ganglion does abolish the pain reflex. The pain of angina is referred to the cutaneous distribution of the first three thoracic spinal nerves of the left side and therefore these nerves must also contain some afferent components.<sup>6</sup> In man pain in the heart and aortic arch is mediated via the middle and inferior cardiac nerves, through the lower-cervical and upper thoracic portions of the sympathetic trunk -- then along the upper thoracic white rami to the corresponding spinal nerves and then to the spinal cord.<sup>6</sup>

The anatomy of the sympathetic innervation of viscera is also important because according to the MacKenzie theory of pain the painful stimulus is initiated in the sympathetic nerve supply of a given organ, it is mediated to the sympathetic trunk and from there to the spinal cord. This irritation of the cord leads to a conscious sensation which is referred by the brain to the exterior segments of the body innervated by the spinal nerve of the corresponding irritated portion of the cord. These facts as will be pointed out later will become of great significance in the development of surgery of the autonomic nervous system.

The physiology of the autonomic nervous system remains a complexity especially the relation of disturbed sympathetic function to disease but correlation with newer anatomical findings and studies upon operative cases promises to shed much light on the subject.

In general the sympathetic division of the autonomic nervous system is excitatory while the parasympathetic system is inhibitory. The antagonistic action of these two systems is everywhere apparent.<sup>2</sup>

The internal organs are supplied with both sympathetic and parasympathetic fibers so that they receive impulses from widely separated centers in the central nervous system.

The action of the sympathetic and parasympathetic systems may be compared to the action of cerebrospinal nerves as flexors and extensors of a given joint. There is a functional balance maintained and a trend toward sympathetic overactivity has been termed sympathicotonia while hyperactivity of the parasympathetic system has come to be known clinically as vagotonia.<sup>2</sup>

Vagus stimulation produces slowing of the heart rate by decreasing conductivity through the A. V. bundle, while stimulation of the sympathetics accelerates the heart rate. Their action is reversed in the intestines where the parasympathetic system causes increased peristalsis and the sympathetic causes slowing. The parasympathetic system inhibits the secretion of

sweat glands, causes constriction of the pupils through pre-ganglionic fibers of the oculomotor nerve and neurons in the ciliary ganglia. The parasympathetic causes relaxation of the pilomotor muscles while the sympathetics cause contraction of these muscles and stimulates the sweat glands.<sup>2</sup>

The function of the sympathetic and parasympathetic divisions of the autonomic nervous system as regards the innervation of blood vessels has already been intimated in the anatomical discussion -- namely that sympathetic fibers cause constriction of blood vessels and parasympathetic stimulation causes dilatation. All arteries and veins with few exceptions do actually constrict in response to sympathetic stimulation while there are no known pathways for the flow of cranial or sacral fibers to the vessels of the extremities or somatic portion of the trunk.<sup>2</sup> Studies after unilateral lumbar sympathectomy on dogs have proven that the temperature of the limb on the operated side was one to four degrees higher than on the normal side and that this elevation persisted for at least two weeks.<sup>7</sup> These findings have been corroborated in the human by Brown and Adson, who state that vasodilatation of arteries of the feet and lower part of the legs is marked as measured by thermometric methods and that the vasodilatation has persisted as long as three years after operation.<sup>5</sup> Other studies prove that sympathetic nerve degeneration is complete following sympathetic gangliectomy so that vasodilatation ought to be permanent following operation and indeed such seems to be the case.<sup>8</sup> Following experimental sympathetic gangliectomy, ramisectomy and trunk resection there has been marked vasodilatation as proven by roentgenograms.<sup>14</sup> There is undoubtedly some vasodilatation following periarterial sympathectomy,<sup>8</sup> but this has been shown by x-ray to be of evanescent character lasting only about ten minutes. Brown and Adson state that the physiological changes occurring after sympathetic gangliectomy are indicative of a profound and apparently lasting effect on the vasomotor nerves with vasodilatation, which is adequate proof of the efficacy of ~~these~~ certain operative measures in certain forms of peripheral vascular disease.<sup>5</sup> Similar physiologic observations have been made with reference to the upper extremities following cervical and thoracic sympathetic gangliectomy and these have demonstrated the same general effects.<sup>5</sup>

A loss of the sweating and pilomotor reflexes <sup>IN</sup> and corresponding areas was a constant observation. Following excision of the first and second thoracic sympathetic ganglia there was no disturbance of cardiac acceleration but a bi-lateral Horner's syndrome of variable intensity and persistence was a constant post operative finding.<sup>5</sup>

Limb development, osseous, muscular and cutaneous was perfectly normal following sympathectomy and muscular atrophy though occasionally observed is transient.<sup>7</sup>

Experiments by F. J. R. Beatie, N. K. Beatie, and T. H. Milroy have shown that muscle metabolism is practically unaltered following sympathectomy both in the resting state and following exercise.<sup>10</sup>

Various contradictory statements have been made regarding the effect of sympathectomy on the blood calcium. Recent studies

by Jose Lamelos have definitely proven that the calcium level remains practically constant whether the sympathetic nervous system is removed en toto or in part.<sup>11</sup>

Surgery of the autonomic nervous system is older than is generally supposed. Interest in the subject has been intermittent however, receiving a new impetus with each new physiological or anatomical discovery.

Jaboulay of Lyons, France was inspired by the work of the physiologist, Claude Bernard, who demonstrated the trophic influence of nerves and the mechanism of vasomotor control of the caliber of blood vessels by the sympathetic nervous system.<sup>9, 12 and 2.</sup>

In 1889 he attempted to apply the above knowledge and performed a decortication of the femoral artery for cure of ulcer of the foot. He observed some of the circulatory phenomena seen today following this operation with some improvement in the peripheral circulation but his results on the whole were by no means striking, his efforts were coldly received, and the work fell into obscurity.

Since arterial decortication or periarterial sympathectomy was the first operation to be performed it is convenient to follow its development up to the present time.

In 1901 Hagier recommended tearing the nerve plexus around the femoral artery in cases of intermittent claudication.<sup>2</sup> This is the single attempt to be found in the literature until the Great War.

Then in 1917 Leriche and Heitz, also of Lyons, France with an improved technique removed the adventitia of the brachial artery and coined the term periarterial sympathectomy.<sup>2 and 12</sup> Leriche's enthusiastic contributions caused a widespread interest and the procedure as described by him has been performed extensively throughout the United States and Europe ever since.<sup>12</sup>

Bruning and Forster in 1922 reported lasting and beneficial results in scleroderma and Raynauds.<sup>2</sup>

In 1923 Bruning used it in trophic and vasomotor disturbances in beginning gangrene.

Kummel in 1924 reported some success with the operation.

By this time interest in the above procedure was universal and periarterial sympathectomy was, and still is for that matter, being performed for almost every ailment known to mankind. Bruning in 1927 still maintained that results were good while others had reported many failures.

Leriche is the outstanding exponent of this form of operation at the present time; he assumes that the vasoconstrictor fibers for cutaneous blood vessels of the extremities have a course like that taken by the fibers for the splanchnic vessels -- that is, join the aorta or other large arteries in the thorax and abdomen and make their way to the periphery in the periarterial plexuses.<sup>6</sup> But I have shown that such is not the case and therefore it becomes very difficult to explain the beneficial results which often follow this operation because they are indeed a contradiction to all of the known facts concerning the anatomy and physiology of the sympathetic nerve system.

Even though it cannot be denied that clinical results are sometimes good in very carefully selected cases, an empirical



operation without anatomical or physiological basis cannot be heartily recommended.

In France Leriche and his followers do it for a good many things but after a careful review of the literature I have decided that this is certainly not the operation of choice, and since it is not I will dispose of it as quickly as possible..

Periarterial sympathectomy has been recommended by many men, Leriche among them, for conditions resulting from vasomotor spasm of the arteries of the extremity,<sup>9</sup> such as Raynaud's disease but a recent study based on clinical results reveals the fact that there is some vasodilatation following periarterial sympathectomy of the femoral artery but that it is transient and concludes further, "Division of the main sympathetic trunk causes a greater and more lasting vasodilatation than periarterial sympathectomy."<sup>13</sup> This fact has been substantiated by roentgen evidence.<sup>14</sup>

Bernheim advocates periarterial sympathectomy in well selected cases and reports a case of arteriosclerosis as the best result he obtained in a series of twenty-eight cases done for various things.<sup>15</sup> In contrast to this Brit warns against periarterial sympathectomy because in a case of presenile gangrene described by him there was extension of the gangrenous process following the operation which necessitated amputation of the leg.<sup>16</sup>

Cotte has been very enthusiastic about pelvic periarterial sympathectomy on the hypogastric and ovarian arteries in pelvic neuralgia with pains in the ovary, uterus, and uterosacral ligament with no lesions on the genitalia. He has reported five cases as cured with no recurrence in ten to fourteen months.<sup>17</sup> There has not been a sufficient number of cases reported to evaluate this procedure with accuracy.

Leriche maintains that results he has obtained by periarterial sympathectomy on the hypogastric and ovarian arteries in certain cases of dysmenorrhagia, metrorrhagia and obscure pelvic pains proves the usefulness of the procedure in these conditions and justifies application to a whole set of syndromes hitherto unresponsive to any form of therapy.<sup>18</sup>

A summary of ninety operations on seventy-two patients as given by G. P. Muller will suffice to reveal the great variety of things for which periarterial sympathectomy has been used as well as the uncertainty of results.

Vascular Diseases	Number of Cases	Benefited Cases
Thrombo-angiitis Oblit.	17	2
Arteriosclerosis	13	2
Raynaud's	3	2
Trophic Conditions		
Scleroderma	1	0
Ulcers		
Trophic	10	6
Varicose	6	5
Miscellaneous		
Cervical Rib	1	1
Thermalgia	2	1
Arthritis Deformans	2	1

*PAIN WAS SOMETIMES HELPED.*

Miscellaneous (con.)

Painful Osteoperiostitis	1	1
Eczema, hand	1	1
Trophic Contracture	1	1

19.

The above report is scarcely conclusive and so it is with most of the periarterial sympathectomies.

Sympathetic ganglionectomy and trunk resection was first performed by Alexander in 1889 who did a bi-lateral extirpation of the superior cervical ganglion for epilepsy. In 1892 Jackson resected the vertebral plexus and divided the sympathetic trunk above and below the middle cervical ganglion also for epilepsy. 2.

Prior to 1896, Jonnesco had done 43 operations of this kind, mostly for epilepsy but the series included eight cases of exophthalmic goitre. 20.

Jaboulay also in 1896 divided the sympathetic trunk above and below the middle cervical ganglion for epilepsy and reported a case of exophthalmic goitre on which he had done a sympathetic ganglionectomy.

In 1897 Jonnesco tried the operation for glaucoma but it was unsuccessful and the procedure has been discarded. 2.

Jonnesco in 1906 again reported a series of cases, this time he gave twelve of one hundred and seventeen cases of idiopathic epilepsy as absolutely cured and twenty-five cases of exophthalmic goitre as completely recovered. 20. These results in epilepsy as reported by Jonnesco were remarkable but since the cerebral vessels do not have vasomotor fibers his theory was incorrect and the operation therefore has no anatomical or physiological basis. It has long since been abandoned even Jonnesco himself having given it up shortly after his report.

The operation for exophthalmic goitre is sound in principle because this type of hyperthyroidism is believed to be due to some abnormality of the sympathetic nerve supply, but thyroidectomy offers a more direct and efficient means of handling this problem so that it has been discarded for thyroid dyscrasias.

From 1906 to 1915 there was definite decline of interest in sympathetic ganglionectomy but it was markedly stimulated again in 1916 by the work of Jonnesco who severed the middle and inferior cervical ganglia and the first thoracic ganglion on the left side only in a case of angina pectoris. This operation was first suggested in 1899 by Francois Franck. There were no effects in Jonnesco's case and convalescence was rapid. The case was pronounced as cured five years later. Another case was also showing good improvement. 20 and 2.

The above operation stimulated a great deal of physiological and anatomical research and this in turn was followed by numerous case reports on angina pectoris by Tuffier, Bruning, Reid and Freidlander, Smith and McCure, Diez, Pleth, Hofer and Eppinger then in 1921 Coffey and Brown. Almost without exception these cases showed improvement and many of them were actually permanently and completely cured. 20.

It has now become a recognized procedure in selected cases of angina pectoris<sup>2</sup> and will be discussed more fully presently.

Royale and Hunter in 1924 performed a sympathectomy for a case of spastic paraplegia. This was done on the theory that spasticity was due to overactivity of the sympathetic nervous system and that in absence of full voluntary control the sympathetic tonus becomes exaggerated. Severing the sympathetic nerves should then allow return of voluntary control thus relieving the spasticity caused by overactivity of the sympathetic nervous system.<sup>2</sup> However, Kanavel and others in study of the sympathetic nerve supply of skeletal muscle have come to the conclusion that the procedure is not well founded.<sup>2</sup> Likewise clinical results while striking in a few instances certainly do not warrant general application for spastic paralyse.<sup>2</sup>

Sympathetic ganglionectomy ramisectomy and trunk resection was next applied to diseases of the blood vessels resulting from vasospasm of peripheral arteries. It has become well established that extirpation of the second, third, and fourth lumbar sympathetic ganglia and communicating rami joining the nerves of the sacral plexus must result in complete sympathetic denervation of the vessels of the lower extremity. In like manner removal of the inferior cervical and first thoracic ganglia results in complete denervation of the vessels of the upper extremity except where there is an inconstant second thoracic ganglion and then it is necessary to divide the sympathetic trunk below this ganglion.<sup>2</sup>

It has been demonstrated that normal vessels following this operation soon regain their tonus but if there is abnormal vasoconstriction before the operation then it permanently increases the blood supply.<sup>2</sup>

It may be well to describe the operative technique of the two procedures outlined above, viz. extirpation of the second, third, and fourth lumbar sympathetic ganglia and communicating rami and removal of the inferior cervical ganglion and the first thoracic (sometimes also the second thoracic) ganglia.

The surgical technique per se, of the sympathetic ganglionectomy, ramisectomy and trunk resection is not especially difficult but it does require a modicum of special training and should not be done in the routine of a busy surgeon's day.

For removal of the second, third and fourth lumbar sympathetic ganglia, rami and trunk an incision is made from the symphysis to a point 7.5 cm. above the umbilicus. Before entering the peritoneal cavity the patient is lowered into the Trendelenburg position insuring better exposure of the sympathetic trunk in this region. The intestines are then gently packed upwards first on either the right or the left side and then on the opposite side. The lumbar sympathetic trunks are easily identified and approached on either side lying on the ventrolateral aspects of the transverse processes of the vertebrae. The second, third, and fourth lumbar ganglia are identified, their communicating rami sectioned and the sympathetic trunk divided and removed. The chief dangers of the operation are, trauma because of too much traction on the mesenteries, and accidental rupture of an intervertebral vessel but these are usually easily ligated and if this proves difficult it is a simple matter to put on a silver clamp.<sup>3</sup>

For removal of the inferior cervical and first and second thoracic sympathetic ganglion a posterior approach to the mediastinum is the method of choice. A mid line dorsal incision is made from the sixth cervical down to the fourth thoracic vertebrae. The second thoracic vertebra and rib are identified, the transverse process of this rib is removed and the second rib three cm. lateral is resected.<sup>22</sup> These are removed with a rongeur. The pleura is thus exposed and is dissected away by blunt dissection. The sympathetic trunk and ganglia are now identified and removed. The above operation is technically more difficult than the preceding one but when properly done there is little shock and complications are relatively infrequent.

To discuss the indications for sympathetic ganglionectomy, ramisection and trunk resection is again very difficult especially since I have promised to avoid controversy. Therefore in a more or less arbitrary manner I have chosen to select four main conditions for which sympathectomy is of indisputable value, indeed in some cases is entirely curative. In all four of these conditions not only was the patient helpless because of his affliction but his prognosis was hopeless before the advent of surgery of the autonomic nervous system.

Sympathetic ganglionectomy, ramisection and trunk resection is of unquestionable value:- in

RAYNAUD'S DISEASE  
HIRSCHSPRUNG'S DISEASE  
POLYARTHRITIS (carefully selected cases)  
ANGINA PECTORIS

Raynaud's disease is a classical example of vasomotor spasm. It is characterized by bi-lateral intermittent ischemia, cyanosis and hyperemia of the extremities, (though it may be of an internal vessel) and the vasospastic attacks are usually either precipitated or made worse by exposure to cold and emotional disturbances. There is characteristic absence of organic disease of the vessels. Therefore the radial and dorsalis pedis arteries are palpable. In the more severe forms the pain is terrific occurring during the time when the extremities are red and swollen and frequently leads to gangrene of the digits.

Ninety to ninety-five per cent of cases are in women and in a period of life before the arteriosclerotic age. This abnormal vasospasm is considered to be due to an overactivity of the sympathetic nervous system so that if all of the fibers which mediate sympathetic impulses to a given extremity were severed then relief from this affliction should be complete. In truth it is complete and permanent following sympathetic ganglionectomy, ramisection, and trunk resection.<sup>30</sup> We are then able to correlate anatomical and physiological facts with clinical results and this is the desirable concept of surgery of the autonomic nervous system that I wish to develop.

Of course even in this disease there are a few failures recorded but these are no doubt due to mistakes in diagnosis and improperly selected cases.

In this connexion Brown in 1923 developed use of the foreign protein reaction to determine suitability of cases for operation.<sup>2</sup> Following foreign protein injection there is a dilatation of peripheral arteries which accompanies the rise in temperature. If there is any organic disease of the vessels they will fail to dilate and the case would not then be suitable for operation. In

this study Brown has found that there is a close parallelism between the elevation following protein injection and that following sympathetic ganglionectomy. The rise in temperature of an extremity should be two or more times the rise in mouth temperature or it is not advisable to do the operation. This is known as the "vascular index".<sup>22</sup>

J. C. White of Boston says that Brown's "protein test" or vascular index is not always reliable. He had developed a method of blocking all of the sympathetic fibers to an arm or leg with procaine which produces for as long as two to four hours all the effects of sympathectomy.

Remembering the anatomical distribution of sympathetic fibers for the upper extremity it is evident that all of these fibers could be completely blocked by injection of procaine along the lateral borders of the bodies of the first and second dorsal vertebrae.

It is possible to cause vasomotor paralysis of the lower extremity by a subarachnoid block reaching to the level of the sixth thoracic vertebra, by injecting procaine along the sides of the lumbar vertebrae, or by blocking the sciatic nerve, in any case interruption of sympathetic pathways is complete and the result is quantitatively analogous to that which will obtain following operation.<sup>23</sup> The patient can realize what he may expect following operation. This injection method with procaine is of definite diagnostic and prognostic value and is being used quite extensively at the present time.

According to Brown and Adson a patient with Raynaud's disease should undergo an operation when:

- Symptoms are progressive.
- Trophic changes are developing.
- The patient becomes incapacitated.
- Other forms of therapy fail to give relief.

The operation is performed as outlined above for either the upper or lower extremities. The results are remarkable, there is immediate relief from pain, the skin becomes warm pink and dry. Old ulcers heal rapidly and nails resume their normal growth. Patients are able to return to their usual work. Some of Brown and Adson's patients have been observed for more than four years now and relief has been complete for the whole of this period. The skin of the affected extremity remains dry but this is relieved by application of olive oil or cocoa butter. Horner's syndrome which is usually present when the upper extremities have been operated is of no consequence if it is bi-lateral but it is troublesome if it is uni-lateral.<sup>24</sup>

Sympathetic ganglionectomy for occlusive arterial diseases such as arteriosclerosis and endarteritis is of questionable value, certainly the rationale for the procedure is not clear. The operation in these diseases is based upon the degree of vasospasm of the unoccluded collateral vessels.

George E. Brown states that results in thromboangiitis obliterans are about the same as in Raynaud's only not so uniform.<sup>24</sup> Many others believe that results are so disappointing that operative measures are to be avoided in this disease. Brown and Adson state that the operation should not be done if relief from pain can be accomplished in any other way.<sup>22</sup> Causalgia, Scleroderma, and Erythromelalgia are also among the diseases for which sympathetic ganglionectomy is of doubtful value so they will not be considered.

Angina pectoris is a symptom complex characterized by paroxysmal attacks of pain, usually pectoral, associated with vascular changes. The vascular changes are vasomotor in character, though there may be organic disease as well, and the excruciating pain is thought to be due to vasospasm of the coronary arteries.

In considering sympathetic ganglionectomy for angina pectoris it should be emphasized that only cases that fail to respond to medical treatment should be operated.

The type of operation to be used should be one of the simplest technique that will interrupt most of the afferent sympathetic fibers to the heart. The least difficult operation is the removal of the superior cervical ganglion with the superior cardiac nerve. If the pain is on the left side only then the operation may be uni-lateral, but if the pain is bi-lateral or the symptoms persist following a uni-lateral operation then a second stage may be done in seven to ten days. This is the technique employed by Coffey and Brown. Other methods are as follows: Jonnesco removed the middle and inferior cervical ganglia and the first thoracic with or without cutting the superior cardiac nerve. Bruning removed only the inferior cervical and first thoracic ganglia while Hofer and Eppinger cut the depressor nerve. Careful study of the anatomy of the sympathetic nerve supply to the heart will show that all of these operations do essentially the same thing -- namely sever the principle afferent pathways to the heart and therefore any of them will give relief from the symptoms of angina.<sup>20</sup>

There are numerous cases reported in the literature and again they vary from astonishing permanent cures to fatalities. Hesse in 1937 summed up the status of surgery in angina pectoris as follows:

65% of cases -- results good.  
17% of cases -- indifferent.  
13% of cases -- fatal on behalf of these were due to heart failure.

He states that in his opinion extirpation of the superior cervical ganglion under local anesthetic is the best operation and that it affords eighty per cent successes and only ten per cent mortality.<sup>21</sup>

In general one should be very cautious if the heart muscle has been damaged. In these cases operative procedure is often too dangerous and if so J. O. White's method of paravertebral injection with alcohol may be employed. For typical left sided angina the paravertebral injection is performed on the upper five left dorsal nerves just lateral to intervertebral foramina. Dr. White's injection method is fairly difficult and potentially dangerous because the injection is made within a few millimeters of the parietal pleura and close to the intervertebral foramina. He suggests that the technique be learned by injection of methylene blue into cadavers.<sup>25</sup>

This method has given complete cure for as long as twenty and twenty-four months in two cases.

The value of sympathetic ganglionectomy in angina pectoris cannot be questioned, it has become a recognized procedure in selected cases.<sup>2</sup> Relief from the painful paroxysms and mental anguish is constant and many claim that relief from pain alone is sufficient to justify the operation.<sup>20</sup> Those cases that die would probably

not have lived anyway and permanent relief from such a painful condition would certainly do a great deal toward restoring an individual to a normal existence whereas without the operation his life would be filled with terror.

Some of the most striking things that I have read concerning surgery of the autonomic nervous system have been in connection with arthritis deformans or nonspecific rheumatoid arthritis. Rowntree and Adson realizing that a new form of treatment in this type of disease was very much needed decided to try sympathetic ganglionectomy on a case of theirs.

The patient was a female age 33 who gave a history of generalized chronic arthritis for six years which was gradually getting worse. Her hands and feet were cold and clammy, the tissues were puffy and there were trophic changes. The areas of cyanosis and moisture were indicative of some disturbance in the vasomotor system. The above changes are similar to the intermittent changes in Raynaud's disease. Since all medical treatment was directed at increasing the blood supply to a limb then a procedure which would permanently do this should afford some relief.

The patient underwent a period of observation in the hospital and all medical treatment was of no avail.

There were exacerbations of her condition, it was worse at menses. She had stiffness and swelling of the interphalangeal joints of both hands, then the wrists then the elbows, shoulders, and in one year the feet, ankles, and knees became successively involved. Motion was very painful.

She was to be dismissed from the hospital but she begged to have something done so the second, third, and fourth lumbar ganglia with the sympathetic trunk on both sides were removed.

Improvement following operation was prompt and astonishing. The feet became warm, dry and pink. A short time following her operation she walked two miles with entire freedom from pain. For two-and-a-half years after her operation the patient said she felt "cozy" from the waist down. Her legs and feet were comfortable and warm all the time. There was no pain, redness, tenderness or swelling of the joints concerned but slight puffiness of the ankles at times. She lived in Northern Canada and walked to and from work in cold winters without experiencing a suggestion of recurrence of arthritis.

During this period the joints of the upper extremity were extremely painful. There was relentless progression of the arthritis in the upper extremities which made it necessary to do all of her typing with one finger. The pain was so severe that the patient could no longer endure it and she had a nervous breakdown. Three months prior to her second visit to the Mayo Clinic she had not had a nights sleep because of pain and limitation in all joints involved was decidedly more marked.

While at the Mayo Clinic she could walk everywhere with ease and entirely free from discomfort. The arthritic process had decidedly progressed in the hands. There was some atrophy of muscles and beginning ulnar deviation. The hands were cold and clammy, cyanotic and moist. There was no grip in either hand -- she could not make a fist with either hand. The fingers were useless and motion was decidedly limited in the fingers, wrists, elbows and shoulders. Motion was distinctly painful. The skin



was atrophic and shiny and the musculature was flabby.

In contrast the lower extremities were shapely and firm. There was no pain on motion, only slight grating in the ankles and knees but this was not accompanied by pain. The feet were warm and dry, the skin was normal in texture and appearance. It was difficult to believe that she had ever had arthritis in her legs.

On November 25, 1928 a bi-lateral resection of the first and second thoracic and inferior cervical sympathetic ganglia and intervening trunk was done. And immediately following operation the hands became warm and dry and a normal pink color. She could make a fist and grip a person's hand.

A bi-lateral Horner's syndrome developed but this did not detract from her appearance.

For the first few days after her operation she suffered a few arthritic pains in the upper extremity but physiotherapy gave prompt relief for these. When the patient left the hospital she declared there was not a sign of an arthritic pain in any of her joints. Her pinched facies had disappeared while the swelling and tremor of her hands was less marked.

The rate and rhythm of the pulse were normal. She had one attack of tachycardia which lasted only ten minutes. This phenomenon has been observed in other cases of cervico-thoracic ganglionectomy. Sweating was absent over the corresponding areas but could be produced by administration of pilocarpine.

The rise in temperature of the hands now corresponded closely with the temperature of the feet after the first operation. The elevation of temperature of the feet had been fully sustained for a period of over three years.

The circulation was very good around the nails, there was no stasis. The patient was dismissed January 7, 1927 practically cured of her arthritis though of course, some of the manifestations of the old process still remained.

The wasting and loss of tone of the muscles together with the beginning ulnar deflection was gradually disappearing. The hands were soft, dry, pink and very warm. New nails had formed that were perfectly normal in appearance.

The patient was finally dismissed on April 9, 1929 and had gained sixteen pounds since her first entrance.<sup>31</sup>

The results of this case are astounding and indicate that in certain types of arthritis there is an overactivity of the sympathetic nervous system producing vasomotor disturbances with cold, clammy, perspiring hands and contributing to muscular spasm and atrophy of the muscles and the resulting deformity.

Pemberton believes that one of the essential features of arthritis deformans is a constriction of the capillary bed which is indicative of sympathetic overactivity especially in those cases associated with pale, cold, clammy extremities.<sup>26</sup> Release from control of this hyperactivity is the basis for this operation.

G. R. Spurling reports two cases in children as completely cured from arthritis deformans following sympathetic ganglionectomy. Spurling had heard of Adson's case and decided to try it on a child of four years. The child had acute rheumatism with fusiform swellings on all joints. The condition was very painful and the extremities were cold.

A cervical sympathetic ganglionectomy was performed and re-



↑  
relief from pain was immediate. Motion soon returned and the child fed itself for the first time in over a year. Two and onehalf months later a bi-lateral second, third, and fourth lumbar ganglionectomy was done with equally as gratifying results. Three months following this operation the child was a happy and contented individual.

The second patient also a child, age seven, was treated in a similar manner and the results were as remarkable as in the first case. 27.

Sympathetic ganglionectomy is not claimed to be a cure-all for all types of arthritis. It would be folly to attempt to cure cases with advanced bony changes by this means.

From the above cases we are able to visualize the type of arthritic case that is best suited for ganglionectomy. The most important item in this form of treatment is the proper selection of cases. The nerve trunks will not regenerate once they are cut and removed so there is no reason why relief should not be permanent.

First there should be no marked bony changes. There should be coldness of the extremities, marked sweating, tender painful and swollen joints. There are trophic changes appearing in the muscles, skin and nails. All cases should be carefully studied.

This field is one of the most promising in the entire scope of surgery of the autonomic nervous system. A few cases are by no means conclusive but they are most encouraging and most men are agreed that the procedure is very helpful in properly selected cases.

The fourth condition for which sympathetic ganglionectomy, ramisection and trunk resection has come to be a recognized procedure is megacolon.

It is now believed, in light of recent observations that the marked dilatation of the colon which appears in childhood is the result of hyperactivity of the sympathetic nervous system. The irritation causing the hyperactivity may be of ganglionic, preganglionic, postganglionic or most probably, central origin.

It has been pointed out that fibers which cause dilatation of the rectum are mediated via the lumbar rami communicantes through the hypogastric and pelvis plexuses. Then section of the entire sympathetic chain below the last white ramus should reestablish the coordinating mechanism by reduction of the overactive sympathetic stimuli. Once again we are able to apply anatomical and physiological facts, to predict what may happen, and what is even more gratifying it does happen.

The two cardinal symptoms of Congenital idiopathic dilatation of the colon are:

Obstipation

Distention of the abdomen.

Secondary symptoms are: Dyspnea with cardiac embarrassment, wide costal angle, thin abdominal wall, diastasis recti, distention of superficial abdominal vessels, toxicosis, and impaired nutrition with loss of weight.

↑  
Judd and Adson have reported two remarkable cases. The first was a child of eleven months whose abdomen had been distended from birth. It had always taken enemas and petrolager. Following a course of dietetic and medical treatment the child continued to lose weight. Enemas had finally failed to produce results and it was necessary for the local physician to remove feces from the bowel with instruments four or five in the

two weeks previous to entrance.

Adson performed a bi-lateral lumbar sympathetic gangliectomy and ramisectomy removing the second, third and fourth lumbar ganglia with the sympathetic chain and all communicating rami were severed.

The post operative course was normal. Oily enemas were given for a few days to soften mucous membranes and feces and milk of magnesia was to be continued for a time after dismissal.

In one month the mother wrote the child was wonderful in every way. The bowels moved daily without enemas or laxatives and stools were normal. By the end of another month the child was still better and in two weeks previous to mother's report she had given only one soap suds and one oil enema.

The second case was six years old and he had complaints similar to those given above. His post operative course was unusually mild. He had a spontaneous bowel movement on the eleventh day. Enemas were given until the twentieth day when they were no longer necessary. 3.

The child returned to the clinic for examination five months later and his activity was now good. He had one or two spontaneous bowel movements daily and a litre of barium now filled the entire colon showing a decrease in the size of the rectum. 3.

Wade and Royale have reported a case of perfect <sup>yes 4/75</sup> five months after operation. They also report four other cases, two of which were good and two of which were unsatisfactory. 2.

There is one other group of cases which offers promise to surgery of the autonomic nervous system. Many men believe there exists or should exist a surgery of pain which is carried out solely as a palliative measure, for those cases who suffer from pain even though they have undergone other types of surgery. 12 and 28.

Von Gaza in 1923 pictured for the profession the case of an individual who exhibits four or five abdominal scars and presents himself still complaining of the same pain that he had had when he first consulted a doctor. Every physician knows several of such cases. As a rule it will be found that these patients demonstrate vasomotor instability; dermatographia and wheel formation on irritation.

He considers these cases as intra abdominal vasomotor and enteromotor neuroses in which the segments of the vegetative nervous system and especially the segments to which the afferent and efferent paths running in the rami communicantes belong are in a condition of neurotic dysfunction. The origin of this dysfunction may be psychic trauma.

If this theory is correct then it would follow that if these impulses were cut off before reaching the spinal cord the pain would be relieved.

Any attempt like the above of course necessitates an exact localization of the pain as to segments and so he injected novocaine segmentally from the eighth to the twelfth dorsal to determine which level abolished the pain.

Then Von Gaza cut the rami communicantes at the proper level removing also the posterior root ganglia. His case resulted in permanent cure.

Archibald of Montreal, Canada has done three such operations;

one ended fatally from a bi-lateral pneumo-thorax while two gave perfect results.<sup>28</sup>

Surgery of the autonomic nervous system for relief of pain is a field which is worthy of study and research. More experience will enable a better selection of cases.

Honan and Thompson say that operations upon the sympathetics are very useful in visceral and pelvic neuralgias. Leriche believes that the greatest advance in sympathectomy has been in gynecology, where many painful pelvic conditions, even inoperable carcinoma of the cervix have been ameliorated.<sup>12</sup>

To add a small amount of personal touch to this article I have taken the trouble to select three cases -- one each of the four main topics I have discussed, (except angina pectoris, because no record of this operation could be found here,) that have been operated in Omaha.

#### Raynaud's.

The first case I wish to report was Dr. Keegan's. I had the good fortune of meeting and talking to this lady on March 24, 1931 when Dr. Keegan presented her to the Douglas County Medical Society.

The patient was Miss Polly Polanski, age 33. Entered the Methodist Hospital, December 29, 1930.

She gave a typical history of Raynaud's -- intermittent pallor, cyanosis and redness of the extremities associated with pain during the red stage. There was profuse sweating of the extremities, radial pulse was palpable but less than normal. The dorsalis pedis artery was palpable but with difficulty. The novocaine paravertebral diagnostic block was done at the first and second thoracic vertebrae. There was a definite second thoracic anaesthesia with increased warmth of the right hand.

The difficulty began about ten years ago when she began to have pain and tingling in her fingers and toes accompanied by discoloration -- blue -- greenish to white -- red to pink. These changes coming on in cold weather and accentuated by exposure to cold. The patient had been to Dr. Buerger's Clinic in New York City without relief.

Physical examination revealed a well developed, well nourished woman of about thirty-five years, general health apparently good.

Extremities. -- The skin was peeling on the tips of the fingers, there was ridging of the nails. The tips of the fingers were almost gangrenous. The hands and feet were intensely cyanotic; the arteries were palpable.

Shortly after entrance into the hospital Dr. Keegan performed a bi-lateral superior thoracic sympathetic ganglionectomy precisely as described previously. Immediately following operation the patient developed some serious respiratory difficulties. Respiration was rapid and shallow but she soon recovered from these.

Progress. -- January 2, 1931. There has been profuse sweating below the nipple line -- it is dry and warm above. The hands have remained dry, warm and pink. They were still slightly swollen and felt a little stiff when the hands were closed.

January 6, 1931. -- Patient is better now. The swelling of hands has somewhat subsided, they are pink, dry and warm at all times. The hands were of nearly normal warmth in sharp contrast to the cold cyanotic feet.

When I saw Miss Polanski, March 24, 1931 her hands felt perfectly normal. Their texture was smooth. They were perfectly dry, pink and warm and free from pain. Her feet were very cold, the skin was shiny, discolored with mottled areas of deep cyanosis and redness. The dorsalis pedis arteries could be felt but with some difficulty on the left side. Miss Polanski is a very happy woman because her operation has restored her to a normal life except for her lower extremities and she anticipates having these operated at a later date.

#### Hirschprung's Disease. ---

A successfully operated case of congenital idiopathic dilatation of the colon is the next case to be reported.

Francis Holbein, an American white girl, age 14, entered the University Hospital, complaining of:

Soiling clothes with fecal discharge.  
Constipation.

Onset and development. -- The patient has soiled her clothes with fecal material nearly every day since infancy. By special encouragement and an attempt to shame the patient it was possible to induce her not to soil her clothes for a few days. She soils herself at school or at any time. The patient admits that she is bashful and sensitive and that she might avoid the soiling if she went to stool as soon as she felt the urge to defecate. Constipation has not been a particularly severe complaint but has been troublesome for some time, there has been occasional catharsis.

Physical examination. -- The patient looks healthy having a boyish appearance. The examination revealed normal findings except the rectal examination which revealed a greatly dilated ampulla.

Palpation and X-ray demonstrate a large sigmoid and descending colon with evidence of muscular activity, not atony. There was no abdominal distention.

Diagnosis, Hirschprung's Disease. -- Operated January 20, 1930, by Dr. Keegan who performed the usual second, third and fourth lumbar sympathetic ganglionectomy on the left side only.

X-ray report three and a half months post operative says that there is now evidence of haustrations in the sigmoid and descending colon with evidence of contractibility of the rectal ampulla. This appearance would suggest a definite improvement over previous film.

Check up also three and a half months post operative reveals that incontinence had ceased, constipation was still troublesome but enemas were needed less frequently and abdomen was less prominent. The colon was no longer palpable. The left leg was warmer than the right. The patient is to return in another six months for a check-up.

The patient was unable to return at end of the six months period but the mother wrote a letter to Dr. Keegan September 20, 1930, saying that the patient had gained weight and grown since her operation. She is keener and more alert than ever before. She seems

to have a real interest in her surroundings and associates which she did not have before the operation and in general she exhibits more confidence in herself. Constipation still somewhat troublesome and at times requires a laxative.

The mother's letter is sufficient testimony of the success of the operation in this case. There is no doubt that the improvement will be permanent, and we now have an effective means of dealing with a problem with which we could do nothing before the advent of this type of surgery.

#### Polyarthrititis --

Mrs. M. E. Smythe, age fifty-two entered the Immanuel Hospital on September 13, 1930. She had been perfectly well up until February 1929 when her fingers became stiff and tender. She had her tonsils out in May 1929. During the summer she had some stiffness, swelling, and soreness in her hands and wrists. Later her knees also became involved and she was confined to bed. Dr. Pratt saw her early in 1930 and she immediately improved. In August 1930 her knees began to get worse. At first they ached and were painful but now they are hot and swollen and cannot be extended.

#### Physical examination.

Extremities. -- The knees were swollen, she could not straighten her knees nor flex them beyond a right angle. They felt hot and tender. The hands were deformed, the process involving chiefly the ring and little finger and the right elbow to some extent.

#### Diagnosis --

Progressive symmetrical arthritis.

Dr. Keegan remarks that patient presents a history of progressive symmetrical arthritis involving chiefly the knees and hands. Not relieved by previous treatment and associated with marked sweating of the hands and feet and cold extremities. X-ray demonstrates that bony changes are not marked, the process being chiefly periarticular

This type of pathology and failure to get relief by other means suggests a prominent sympathetic factor and warrants a sympathetic ganglionectomy.

On September 15, 1930, a bi-lateral lumbar sympathetic ganglionectomy was performed by Dr. Keegan.

September 16, 1930 -- the patient had very little post operative reaction. There was increased <sup>warmth</sup> of both hands and feet. There was no sweating of the feet. There was less pain and stiffness in the knees and she could also move her fingers better.

September 18, 1930 -- the patient can now flatten her knees on the bed and move them freely which she could not do before the operation.

September 22, 1930 -- there is some pain and tenderness in the knees today but they can be moved and straightened out without much limitation.

September 24, 1930 -- the extremities are warm and dry. There is a little pain. The knees seem a little more stiff and painful than immediately post operative.

October 1, 1930 -- the knees continue slightly painful -- the feet are now perspiring slightly and are a little cold. She cannot straighten her knees as well as she could immediately after the operation. The patient states that her feet do not get blue and her knees do not swell as before when sitting up. She is rather weak and unable to walk.

This case could not be considered a complete success, though there has been some improvement since operation. It is possible that all of the fibers to the lower extremities were not cut since there was still some perspiration of the legs and they remained cold. But let it be remembered that experience in selection of cases will do much toward decreasing the number of failures. This case has been inserted least I have been too optimistic in presentation of this subject for I am not unmindful that years of clinical experience are needed to minimize the errors, whether they be in selection of cases or in the operations themselves.

#### Summary:-

The knowledge of the sympathetic nervous system has been increased by an abundance of recent anatomical and physiological research.

With this increasing knowledge there is gradually evolving a very special branch of surgery which I have chosen to designate, surgery of the autonomic nervous system.

Two separate procedures have been employed for various conditions:-

First the periarterial sympathectomy of Leriche, this form of operation I have disposed of because it does not conform to our anatomical and physiological concepts.

Second - Sympathetic ganglionectomy, ramisectomy and trunk resection, this operation in the light of the present day information is the best form of surgical attack upon the autonomic nervous system.

I have deplored the hit and miss, trial and error method so evident in much of the current literature and tried to emphasize fundamentals of anatomy and physiology so that surgical intervention in Raynaud's disease, Hirschprung's disease, Polyarthrititis and Angina pectoris would seem logical, in selected cases that have failed to respond to other forms of treatment. These four conditions, in my opinion are most effectively relieved by ganglionectomy.

Also I have tried to stress the importance of careful selection of cases for herein lies most of the success or failure of surgery of the autonomic nervous system.

This subject should be approached in the true scientific spirit, with open minded skepticism and a realization that as our knowledge of the anatomy and physiology of the autonomic nervous system is increased so will the scope of surgery of that system be enriched.

Whatever is accomplished in this field is a distinct contribution to the progress of medicine as a whole because even today it has restored to useful citizenry many a life that would have been helpless without surgery of the autonomic nervous system.

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