Close structural connections were found between the reticular and epithelial tissues in both layers of the thymus lobules.

The discovery of all components of reticular tissue in the thymus confirms the correctness of the earlier hypothesis that reticular tissue, as the source of histogenesis of other forms of interstitial tissue, is present in all organs without exception [4].

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# MORPHOLOGICAL ASPECTS OF AUTOGRAFTING OF A SYMPATHETIC GANGLION IN THE REGION OF HEMISECTION OF THE SPINAL CORD IN CATS


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Peripheral ganglia have been transplanted into brain tissue by Ranson [8, 9], Tidd [10], and Clark [7]. As the graft they used spinal ganglia which, after extirpation, were transplanted into the cortex of the experimental animals (rabbits or rats). The results of these experiments showed that the nerve cells of a ganglion could survive for up to 3 months, that the graft was slowly resorbed, and that it stimulated regeneration of the injured area of cortex. These workers did not undertake longer observations. In the accessible literature, no indication could be found to the use of ganglia of the sympathetic trunk in neuroplastic operations on the CNS.

Meanwhile, Soviet investigators [1-4] have shown that sympathetic ganglia can be effectively used to create new nerve centers and pathways of reinnervation for some internal organs. My own preliminary observations [5, 6] also demonstrate the high plasticity and powers of regeneration of nerve cells of the sympathetic ganglion after total transverse section of a preganglionic trunk or of the ganglion itself.

This paper gives the results of autografting of sympathetic ganglia on a nutrient pedicle, consisting of preserved interganglionic branches of the sympathetic trunk, into the region of hemisection of the spinal cord.


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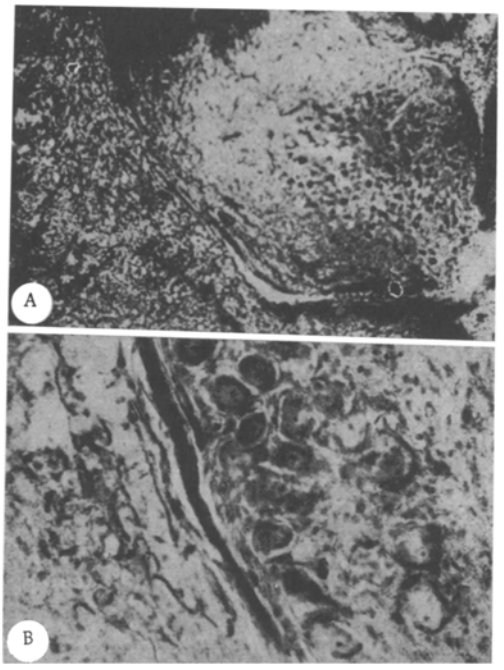


Fig. 1. Structure of transplanted sympathetic ganglion 10 days after operation. A) General view of ganglion containing sympathetic neurons (n). Impregnation with silver, 56×; B) ectopia of nuclei, total or partial chromatolysis of sympathetic neurons. Stained with cresyl violet. 280×.

## EXPERIMENTAL METHOD

Experiments were carried out on 40 cats. In 15 of the cats the cranial cervical sympathetic ganglion was isolated by removal of the capsule and blocking of connections at its upper pole, after which the ganglion was transplanted, together with the preserved preganglionic sympathetic trunk, located caudally to the ganglion, into the region of lateral hemisection of the 3rd cervical segment of the spinal cord. The ganglion to be transplanted was brought up to the spinal cord through a hole in the body of the 3rd cervical vertebra. In 15 animals lateral hemisection of the spinal cord was carried out at the level T13 or L1. The 3rd or 4th ganglion of the lumbar sympathetic trunk was then transferred into the region of injury, through a hole in the arches of the corresponding vertebrae, on a nutrient pedicle consisting of preserved interganglionic branches, lying cranially, relative to the ganglion. Ten animals with hemisection of the spinal cord at levels C3, T13, and L1 served as the control. Observations continued for between 6 days and 1 year.

The transplanted ganglia together with adjacent segments of the spinal cord served as material for histological investigation. The material was impregnated with silver by the Bielschowsky–Gros, Cajal, and Rio-Hortega methods and stained by Mallory's and Nissl's method. Succinate dehydrogenase (SDH) activity was determined histochemically by Nachlas' method. For electron microscopy the UEMV-100 instrument was used.

## EXPERIMENTAL RESULTS

Many neurons with signs of partial or total chromatolysis in the cytoplasm were seen in the transplanted ganglion 1-2 weeks after the operation (Fig. 1). Marked degeneration of most nerve fibers was observed in the preganglionic sympathetic trunk. Around the ganglion on the boundary with the spinal cord, a very thin connective-tissue scar had formed, distinguishable only under the microscope, into which regenerating blood vessels were growing from the side of the spinal cord and also from the side of the graft, most of them running in a circular direction. A few macrophages appeared in the scar, among which small unbranched "monocyte-like" forms were predominant; round cells with granular cytoplasm and solitary microglial cells also appeared. Starting from the end of the first week, marked regeneration of thin nerve fibers running toward the graft could be seen in the injured regions of the spinal cord.

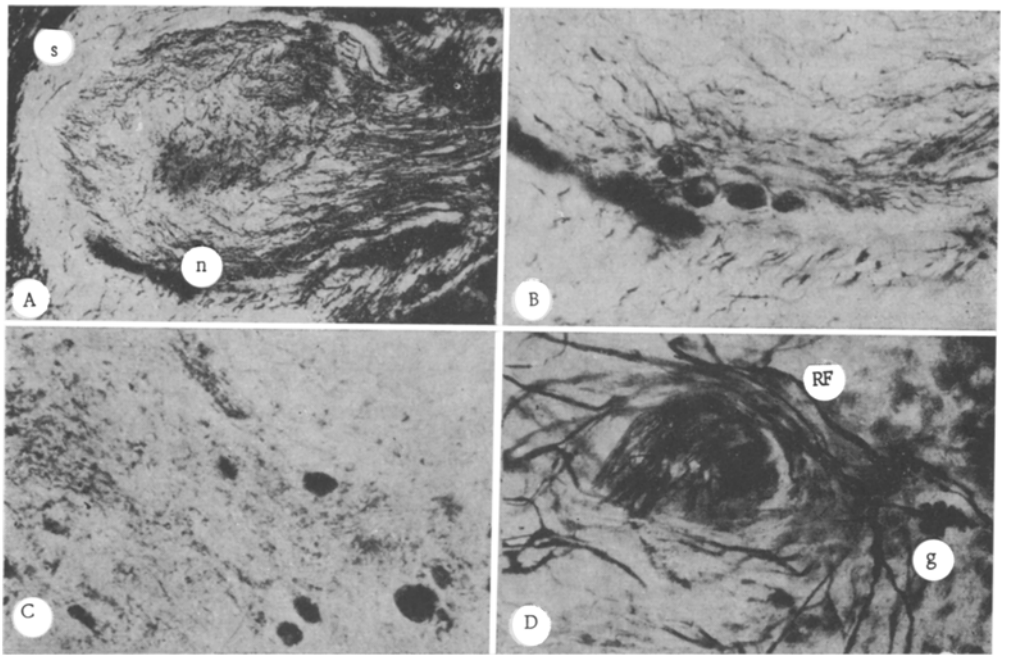


Fig. 2. Structural changes in region of transplantation at late stages of experiment. A) Regenerating nerve fibers in sympathetic trunk, transplanted ganglion, and surrounding connective-tissue scar (s). Small groups of neurons (n) can be seen. Four months after operation. Impregnation with silver, 56×; B) part of same preparation containing group of neurons (n) surrounded by square. 280×; C) SDH activity in neurons of transplanted ganglion 1 year after operation. Method of Nachlas et al. 280×; D) Nerve fibers of spinal cord, including regenerating fibers (RF) and their endings, discovered in close contact with graft (g). Ten months after operation. Impregnation with silver. 420×.

The number of neurons in the ganglion was sharply reduced after 3-4 weeks. The preserved groups of neurons had close to the normal structure of nuclei, bodies, and processes and they lay at the periphery of the ganglion or nearer to the preganglionic trunk. Single nerve fibers, a dense network of capillaries, numerous spindle-shaped fibroblasts, and branching macrophages, characterized by SDH activity and containing basophilic granules, also appeared in the graft. In place of the dying neurons, bands of connective tissue were developing in the ganglion. The dimensions of the graft and of the surrounding connective-tissue scar were practically unchanged, and on the boundary with the decapsulated regions of the ganglion the thickness of the scar was minimal. On the side of the spinal cord marked regeneration of nerve fibers, as a rule branching near the graft to form thinner collaterals with a predominantly circular distribution, continued. In the same zone many nerve endings could be seen in the form of neurofibrillary loops and receptor-like tufts, and under the electron microscope axon terminals containing synaptic vesicles could be seen. Some regenerating nerve fibers of the spinal cord invaded the ganglion, forming a complex ramification of terminals with numerous synapse-like endings. Regeneration of intraspinal fibers corresponded to regeneration of processes of the oligodendroglia. An appreciable increase also was found in the number of microgliocytes on the boundary with the graft. Compared with the control, proliferation of astrocytes was less intensive.

Rapid regeneration of sympathetic nerve fibers was observed in the transplanted ganglion 1-2 months after the operation. Some fibers were growing into the ganglion from the side of the preganglionic sympathetic trunk. Another source of regeneration was the processes of sympathetic neurons, which during growth and branching became thinner and formed multiple fine terminals, interwoven haphazardly in the stroma of the ganglion. Among the regenerating nerve fibers and on the neurons of the graft, sympathetic structures were found. Some of the sympathetic fibers broke through the scar barrier and invaded the tissue of the spinal cord to various depths. Sometimes their endings could be detected in the form of delicate neurofibrillary loops or rings. It can only be suggested that these formations were true synapses, establishing functional connection between the graft and the spinal cord. However, many of the sympathetic nerve fibers penetrating into the spinal cord showed evidence of delayed growth: a helical arrangement close to the graft, the appearance of

many large varicosities along the course of the fibers, the formation of "giant" growth bulbs, and so on. Regeneration of nerve fibers in the ganglion, although gradually subsiding, continued for 3-6 months and ended with permanent reinnervation of the graft (Fig. 2A, B, D). The thickness of the scar in the spinal cord was not increased at this period. Only some increase in the density of the connective tissue could be observed in the stroma of the ganglion, with a considerable increase in the quantity of microglia in the nearby segments of the spinal cord. The capillary network of the graft and of the spinal cord scar remained well developed.

Toward the end of the experiment, after 8-12 months, small groups of neurons with near-normal structure or characterized by the presence of reactive changes – irregularity of outlines of the dendrites, eccentric position of the nuclei, coarsening of the neurofibrils, and argentophobia of the neurons – appeared in the ganglion. Nevertheless, in most of the residual neurons high SDH activity was found (Fig. 2C). The graft was well vascularized and reinnervated. Numerous nerve fibers of different caliber and nerve endings were visible in the preganglionic trunk, the stroma of the ganglion, its capsule, and the surrounding connective-tissue scar (Fig. 2D). Regeneration of nerve fibers of the spinal cord toward the end of the experiment was largely completed, although in the late stages, among intraspinal fibers closely connected with the graft individual fibers with signs of regeneration could still be seen (Fig. 2D). In the spinal cord close to the ganglion, proliferation of astrocytes of moderate degree compared with the control was observed; their processes in some places, where the capsule of the ganglion was absent, invaded the graft to different depths. Where the connective-tissue capsule was present or there were well-marked scar changes, penetration of astrocytes was limited to the region of the scar in the spinal cord. Meanwhile, processes of oligodendrocytes as a rule accompanied the regenerating nerve fibers and could be traced along almost their entire length. No marked obliteration of small vessels was observed.

Autografting of a sympathetic ganglion connected with the preganglionic sympathetic trunk into the region of hemisection of the spinal cord thus leads to the development of complex processes of degeneration of regeneration, both in the graft itself and in adjacent segments of the spinal cord. In the course of 2 weeks, destruction of most neurons and nerve fibers in the transplanted ganglion is observed. The remaining neurons of the graft persist for 1 year and, having a near-normal structure, their processes have the ability to regenerate. Another source of regeneration of nerve fibers is the preganglionic sympathetic trunk. Regenerating sympathetic nerve fibers penetrate the whole stroma of the ganglion and are able to penetrate through the surrounding connective-tissue scar into the tissue of the spinal cord, thereby forming nerve endings whose functional role is still unexplained. From the side of the injured segments of the spinal cord intensive and prolonged regeneration of nerve fibers directed toward the graft is observed. Intraspinal nerve fibers, crossing the scar-tissue barrier, can spread "en passant" into the spinal cord tissue or ramify, to form nerve endings in the zone of the scar and in the ganglion itself. Regeneration ends with well-marked reinnervation and and revascularization of the transplanted ganglion and of the connective-tissue scar of microscopic size surrounding the ganglion, and with negligible development of dense connective tissue.

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