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NERVE GROWTH AND NERVE REPAIR*

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This is a war of nerves in more than one sense. The incidence of nerve injuries is likely to be high, disability resulting from permanent loss of sensation and movement serious. A limb whose nerves are cut is useless: communication lines gone, brain and spinal cord can no longer control it. Not unless and until the lines are restored. Fortunately, the damage need not be irreparable. Nerves have the power to regenerate. If we wisely help their efforts, nerve regeneration will lead to functional repair.

A nerve is a cable of microscopic threads, each one-thousandth to one ten-thousandth of an inch thick. Each fiber consists of a core or axis, embedded in a string of accessory cells, the whole enclosed in a tubular sheath. The axis is the conductor in which the nerve impulses travel. The surrounding cells presumably have nutrient function, and the sheath serves as container. Each axis fiber originates from a cell in a nerve center, such as brain or spinal cord; its very life depends on its remaining connected with that cell. When divided, the cut off portion disintegrates, while the sheath survives. Figuratively speaking, the isolated fragment becomes a roadbed without rails, and impulse traffic ceases.

To restore traffic, new conductor lines must be laid. This is done by the proximal fiber stumps rooted in the central cells. Their tips begin to move forward, and as they grow, the stump is spun out to greater and greater length; the fiber regenerates. Here, then, are the threads to reweave the torn fabric of nerve connections; can they be guided into a useful pattern instead of a chaotic tangle? They can with our help.

The deserted tubes of the disconnected distal end make good conduits for growing nerve sprouts. The problem is to direct the fibers into those conduits. The greater the gap between the stumps, the more pathless distance the fibers will have to span. How do they do it? It has been contended that nerve fibers are attracted toward their destinations by chemical emanations or electric forces. They are neither one nor the other. Their only

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guide is contact with surrounding structures to which they cling like climbing vines. This fact has been revealed and firmly established by experiments which I have carried out since 1927, using the method of tissue culture which was devised for just such purposes by Harrison more than thirty years ago. I demonstrated that tension applied to a colloidal culture medium will produce an oriented fibrous structure, and that cells and nerve fibers growing in such a medium will then follow the fibrous pathways along the lines of stress. In an unoriented medium, growth runs wild and ends up in a tangle.

Nerve surgery aims at channeling the nerve stream from the proximal into the distal stump. However, scar tissue tends to form between the stumps, and this tends to deflect and obstruct the outgrowing fibers. Even sewing the nerve ends together does not prevent the confusion and dissipation of fiber growth at the suture line.

It is at this point that the lessons of our earlier experiments on nerve growth become applicable. Heeding those lessons, I have arrived at a method which insures superior and unimpeded nerve regeneration in experimental animals. It consists of joining the severed nerve ends inside a fitting cuff of live artery. The elasticity of the link permits tension to be transmitted to the tissue filling the gap so as to produce in it straight and direct rails for the transit of nerve fibers and cells from one stump to the other. Moreover, it shuts the fibers in and scar tissue out. At the end of several months, nerves thus united show hardly any trace of the former damage. However, the method has yet to stand its clinical test. Until then, its value for human nerve repair remains problematical. So much about the reunion of nerves after mere severance.

The bridging of larger nerve defects offers more serious difficulties. As we have said before, the best pipelines for nerve growth are the deserted tubes of a disconnected nerve. The insertion of such nerve segments into large gaps, a method known as "nerve grafting," has, therefore, been practiced with some success. One of the main problems, however, is where to get a piece of nerve for the purpose without sacrificing some good nerve to repair a bad one. Past attempts at using animal nerves or human nerves from amputations after preservation in alcohol or formaldehyde proved wholly unsuccessful. Such grafts turn into tough cords practically impervious to nerve growth. Some recent experiments of our laboratory seem to point a way out of the dilemma. With the assistance of my former student, Dr. A. Cecil Taylor, I tested the effect of quick-freezing and drying on nerves. It turned out that such nerves, when reimbibed and used as grafts, served excellently as conduits for regenerating nerve fibers. Again, our results are thus far confined to animals. But if the method could be adapted for clinical use, it would solve the supply problem of nerve grafting. For, nerves of amputated limbs, which would otherwise be discarded, could be frozen, dried and stored in this condition for later use as grafts.

These are only samples of the many efforts currently under way, striving for improvement in nerve repair. Fortunately, these efforts can proceed from a much firmer foundation of knowledge about nerve growth than was available during the last war. It is gratifying that our years of prying into the mechanism of nerve growth may benefit the practice of nerve repair. But, to be honest, this was not our primary objective when we started our research. We were simply interested, purely scientifically, in what makes nerves grow and how and why; not just human nerves; any nerves, frog and chick and rat. Such basic knowledge furnishes the keys for practical applications as surely as trees bear fruit. But you cannot raise fruits by short cuts. You have to raise the tree. You have to make the tree of knowledge grow *as a whole* in order that in due course you may reap the fruits that wil benefit your health, security and comfort. I think the story I have told you illustrates the point.