lation which can more readily be restored to a coördinated beat with an electric shock. (4) In extreme dilatation which may follow a toxic dose of procaine, dilute solutions of calcium chloride and adrenaline in small doses are antagonistic and aid in producing the necessary condition for restoration of a coördinated beat. (5) When a feeble beat has been restored, gentle massage and, if this is ineffective, cautious administration of calcium chloride and adrenaline[6] aid in restoring a vigorous heart beat. When procaine has been given previous to electric shock, there is little tendency to return to fibrillation unless excess calcium chloride is introduced. The heart must be carefully observed, for a period of about 20 minutes before the chest is closed, for acute dilatation during the recovery phase.

In summary, a proper state in the fibrillating ventricular myocardium can be obtained by the careful use of myocardial depressant drugs and their antagonists, which makes it possible almost routinely to revive the heart from ventricular fibrillation. The chances of permanent recovery depend upon the magnitude of the operative procedure. In 25 consecutive cases of ventricular fibrillation in dogs the author has been able to restore a normal heart beat by using the foregoing technique. Many of the hearts were severely damaged by contusions, stab-wounds, etc. As long as 30 minutes have elapsed before revival with complete postoperative recovery, and no signs of cerebral injury. Even though difficult to develop, this technique is feasible and should be available for use in the operating room in cases of ventricular fibrillation.

9340 P

Quantitative Studies on Nerve Regeneration in Amphibia. I. Factors Controlling Nerve Regeneration in Adult Limbs.

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Nerve regeneration is the result of a growth process starting from the cut ends of those parts of the severed neurones left in connection with their cell bodies. Extensive bifurcation of the outgrowing sprouts is supposed to provide for overabundance of peripheral terminations. To what extent the excess of innervation is kept within bounds, and by what factors, has not yet been deter-

[6] Hooker, D. R., *Am. J. Physiol.*, 1930, **92**, 639.

mined. Observations showing that the number of regenerated nerve fibers in supernumerary transplanted limbs is of the order of that of a normal limb, irrespective of the size of the nerve source, (Weiss[1]) suggested the existence of peripheral influences controlling the amount of fiber regeneration.

Following this lead, a series of experiments was undertaken on adult specimens of the Japanese newt, *Triturus pyrrhogaster* (Boie). Operations were performed on the brachial plexus (spinal nerves 3, 4 and 5) of one side, the opposite side serving as control. After the operation, 120 days were allowed for nerve regeneration, whereupon experimental and control limbs were fixed and treated by Bielschowsky's silver method. Nerve counts were made in cross sections at 3 representative levels (H, *proximal humerus;* E, elbow; W, proximal wrist), and the percentage difference between the number of regenerated fibers in the operated limb and the number of original fibers in the control limb was calculated.

Experiment I. (7 cases.) Transection of all brachial nerves at the shoulder level. A fiber deficit was found in the regenerated nerves, the average percentage difference amounting to, at H: 15.4%; at E: 27.2%; at W: 45.6%. This deficit seems to parallel a certain atrophy of the denervated and re-innervated limbs, the average reduction of their cross-sectional area being 21.5%. The number of nerve fibers entering the limbs (at level H) is, therefore, grossly speaking, of the same order before and after nerve regeneration.

Experiment II. (5 cases.) After transection of the brachial nerve plexus, the proximal stump of the fourth spinal nerve which is the strongest of the plexus, was inserted into shoulder muscles so as to prevent it from contributing fibers to the free limb. By this means the source of fibers available for the latter was restricted to the third and fifth nerves, which meant a reduction to about one-half of the source available in experiment I. After 120 days, the average percentage differences were found to be, at H: 20.2%; at E: 50.8%; at W: 52.2%. These figures show that the conspicuous reduction of the amount of fiber stumps available for regeneration has failed to cause a corresponding, or even an appreciable, decrease in the number of fiber branches entering the limb (at level H; compare with Exp. I).

Experiment III. (5 cases.) After transection of the brachial nerve plexus the distal fragments of the severed nerves were extirpated as far distally as possible, eliminating thus a great deal of

[1] Weiss, Paul, *J. Comp. Neurol.*, 1937, **66**, 481.

the pathways (Bungner's cords) preferentially followed by regenerating fibers. Here, the deficit was considerably greater than in experiment I, namely, at H: 42.2%; at E: 67.2%; at W: 67.5%.

Experiment IV. (6 cases.) Combining the operations of Exp. II and Exp. III. The differences were, at H: 39.4%; at E: 64.7%; at W: 68.8%. Comparing these figures with those of Exp. III, one notices again that the reduction of the proximal nerve source has failed to entail a corresponding reduction in the amount of fibers found within the limb. The absence of the peripheral sheaths, on the other hand, has caused in every case a material reduction in the peripheral supply (compare Exps. II and IV with I and III).

The data obtained seem to indicate that, (1) the branching of regenerating fibers is extensive enough to permit practically full reinnervation of a limb even from an undersized nerve source; (2) the degree to which a limb is repleted with regenerated fiber branches is controlled by factors residing within the limb and tending to limit the actual supply to approximately the normal amount; (3) the degenerating peripheral nerves may represent one major factor exerting numerical control over the admission of new fiber branches; but even in their absence the limb tissues seem to continue to exhibit a certain degree of control.

9341 P

Quantitative Studies on Nerve Regeneration in Amphibia. II. Innervation of Regenerated Limbs.

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When the developed limb of a urodele amphibian is amputated, masses of mesenchym accumulate at the wound and by subsequent growth and differentiation produce a new limb. Concomitantly, nerve fibers sprouting from the severed old nerve trunks invade the regenerating limb and provide its nerve supply. This process, studied in a preliminary manner by Weiss and Walker,[1] was given a more thorough examination in the present study.

Adult specimens of the Japanese newt, *Triturus pyrrhogaster* (Boie) and Mexican Axolotls were used, the latter in 2 different size (age) groups (75-85 mm. and 120-150 mm. in length). Fore

[1] Weiss, P., and Walker, R., PROC. SOC. EXP. BIOL. AND MED., 1934, **31**, 810.