with octavo pamphlets. The publishers of some other periodicals are equally accommodating, and I have had quarto and octavo reprints made from one that has folio pages, with no extra charge.

Even before an article is set up the author can take some precautions for the benefit of his readers. It would be too much of a digression to point out many of them here, for this is not an essay on how to prepare manuscripts for publication;[2] but attention might be called to one desirable reform, namely, restricting the number of joint contributions. Every book or paper by two or more authors, especially if new species are described in it, makes extra trouble for librarians, bibliographers, biographers and others, as long as a copy of it exists (which may be for several centuries). Usually most or nearly all of the writing of a joint paper is done by one of the authors, and the assistance of the other can be fully acknowledged without putting his name on the title-page. In cases where one author is much older or better known than the other the latter doubtless feels honored in having his name publicly associated with the more noted man's; but reputation is a scientist's most precious possession, and no true scientist should wish his to be mixed with any one else's. (Nearly all the great masterpieces of science are each the work of one man.)

For the benefit of librarians I will close with a protest against the common custom of discarding the covers and advertising pages of magazines when they are ready to be bound. The stock excuse for this is that it is done to save space; but few scientific libraries are so cramped for space that they can not spare a few inches more a year for advertising pages. It is very interesting to look through the outer pages of old numbers of Science, for instance, and see what text-books and apparatus were in use at a given period, and sometimes one can get valuable evidence of dates of publication in that way.[3] There is perhaps no better place than the advertising pages of the popular literary magazines to trace the historical development of bicycles, automobiles and innumerable other familiar articles.

Covers help to locate articles in a volume quickly when one knows the month but not the page, and they often bear dates, tables of contents, and other information that is not given in the magazine proper. On the third cover page of the *American Journal of Science* for January, 1877, an important astronomical discovery was announced, but those who do not preserve the covers can trace it back only to the February number, where it was printed again on the regular pages. Early in the history of the same magazine the covers of some of the numbers bore a list of places where it was kept on sale, which is of considerable interest, including as it does some towns that have now almost disappeared from the maps.

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[2] For some valuable suggestions along this line see W. M. Davis, *Pop. Sci. Monthly*, 78, 237–240, March, 1911.

[3] See *Torreya*, 7, 170 (footnote), Aug., 1907.

## SPECIAL ARTICLES

### EXPERIMENTS ON MOTOR NERVE REGENERATION AND THE DIRECT NEUROTIZATION OF PARALYZED MUSCLES BY THEIR OWN AND BY FOREIGN NERVES

During the past three years, I have been investigating the question of the physiological regeneration of motor nerves when directly implanted into paralyzed muscles, and the possibility of the reestablishment of normal neuro-motor connections. In these experiments a remarkable difference in the behavior of the muscles' own nerve and that of foreign nerve was found.

The experiments were made upon the nerves and muscles of the thighs of rabbits. For the electric stimulation a weak current from a Porter induction coil was used, and the nerves and muscles were always freely exposed, so that the effect of the direct stimulation of one or both could be carefully controlled. It is hardly necessary to state that experiments of this kind must be done with great care, that regeneration of divided nerves must be prevented when so desired by extensive resections of the nerves, and that the operator must be certain

that the muscle has been paralyzed by the division of all of its nerve supply. In all of the experiments, unless otherwise stated, the central connection of the nerves remained intact.

1. In the first series of experiments all of the branches of a nerve to a muscle were cut and then reimplanted into the same muscle. In the second series, after the wide excision of all of the nerves to a muscle, a motor nerve which supplied another muscle was cut and implanted into the paralyzed muscle.

It was found in all these experiments that after from eight to ten weeks, electric stimulation of the implanted or the reimplanted nerve was followed by a good contraction of the muscle.

*Conclusion.*—In agreement with Heineke, Erlacher and Steindler, direct neurotization of a muscle paralyzed by separation from its motor nerve supply is possible. After eight to ten weeks, the connections between the nerve and the muscle fibers have been reestablished.

2. Eight weeks after the resection of all of the nerves to a muscle, the wound was reopened and the muscle was examined. The muscle appeared pale and shrunken, and would not contract or would contract only very weakly upon direct stimulation by a strong electric current. A motor nerve from another muscle was then divided and was implanted into the atrophied muscle.

Eight to ten weeks later the muscle had regained its normal appearance, and electric stimulation of the implanted nerve was followed by a good contraction of the previously atrophied muscle.

*Conclusion.*—Neurotization of a muscle which has been deprived of its nerve supply for many weeks is possible. The muscle tissue regularly regenerates under the influence of the regenerating motor nerve which has been implanted.

3. (*a*) Into a muscle with its nerve supply intact, the motor nerve from another muscle was implanted.

Eight to ten weeks later, stimulation of the normal motor nerve to the muscle caused a good contraction, while stimulation of the implanted nerve was without result.

(*b*) The normal nerve to the muscle was then widely resected and the wound closed. When the wound was reopened eight to ten weeks later, the muscle had a normal appearance, and the normal nerves to the muscle had not regenerated. Now, however, a powerful contraction of the muscle followed the electric stimulation of the implanted nerve.

(*c*) In a few of the experiments described under (*a*) stimulation of the implanted foreign nerve caused a contraction of the muscle, but the muscle could no longer be made to contract when its normal nerve was stimulated.

*Conclusions.*—Hyperneurotization of a normal muscle is impossible. *A normal muscle can not be made to take on additional nerve supply.* The implanted nerve can not make any neuro-motor connections and its stimulation will usually fail to have any effect upon the muscle. *If, however, the muscle is permanently separated from its original nerves, then the implanted nerve—which had been hitherto unable to form a connection with the muscle fibers—will establish neuro-muscular connections, and electric stimulation of the nerve will soon cause normal contractions of the muscle.*

4. (*a*) The same experiment as in No. 3 (*a*) was performed, namely, the motor nerve from another muscle was implanted, and in addition the normal nerve to the muscle was cut outside of the muscle and the ends of the cut nerve at once united again by suture.

After eight to ten weeks, stimulation of the implanted nerve was without result, while stimulation of the normal nerve to the muscle (which had been divided and at once united by suture) either above or below the point of division caused a good contraction of the muscle.

(*b*) Both the foreign implanted nerve and the normal nerve to the muscle were cut and the ends of each at once united by suture.

After eight to ten weeks, electric stimulation of the normal nerve either above or below the point of division and suture, caused a contraction of the muscle. Stimulation of the implanted nerve was without effect upon the muscle.

(*c*) The normal nerve was cut near the muscle and was at once reimplanted into another part of the muscle. A foreign motor nerve was also implanted into the same muscle.

After eight to ten weeks, the muscle contracted upon stimulation of the normal (reimplanted) nerve, but not upon stimulation of the foreign (implanted) nerve.

*Conclusions.—Under similar conditions, the normal nerve to a muscle will regain its motor connections with the muscle fibers and will in some way prevent a foreign nerve which has been implanted at the same time from making any effective neuro-muscular connections.* It is impossible to state whether this is due to a more rapid regeneration of the normal nerve or to the fact that the regenerating normal nerve has an inhibitory influence upon the intramuscular regeneration of the foreign implanted nerve. The axis cylinders of the normal nerve to the muscle seem to be able to reestablish their former connections with the end plates or bulbs or to form new end organs more quickly or more powerfully than do those of a nerve which had belonged to a different muscle.

These experiments prove that if a muscle has once its normal nerve supply no other motor nerve is able to make neuro-muscular connections with the same muscle; and that if the normal nerve is cut and reimplanted into a muscle and at the same time a foreign motor nerve is also implanted into the same muscle, only the former will make neuro-muscular connections. The experiments are being continued.

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## THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

### SECTION B—PHYSICS

The recent, December 26–30, 1916, meetings of Section B of the American Association for the Advancement of Science were, as usual, held jointly with the American Physical Society. President R. A. Millikan, of the Physical Society, and Vice-president H. A. Bumstead, of the American Association for the Advancement of Science, alternately presided.

The address of the retiring vice-president of the association and chairman of Section B, Dr. E. P. Lewis, printed in full in Science, December 29, 1916, was an admirable summary of the numerous researches and important discoveries recently made in spectroscopy.

The symposium held jointly with Section C, was on the "Structure of Matter." The eight invited papers together with their formal and informal discussions occupied an entire day, and aroused exceptional interest. Indeed the interest was so pronounced that it has been decided to have as many as possible of the formal papers published in Science.

Other matters of interest to physicists were: some 60 technical papers, representing a wide range of investigations, presented and discussed at the joint meetings of Section B and the Physical Society; recent additions to the equipment of the laboratories of Columbia University; exhibits of apparatus and results loaned some by other universities, and some by manufacturers; and the usual physics dinner.

The number of physicists that attended these meetings was unusually large, but should have been even larger. No scientist can afford habitually to ignore these great gatherings of creative workers, nor can any university afford to tolerate such apparent indifference—for the reputation of a university is the reputation of its faculty and nothing more.

Just before adjourning a well-deserved vote of thanks was extended to the officers and faculty of Columbia University for their courteous hospitality that so materially had contributed to both the pleasure and the success of the meetings.

At present the officers of Section B are as follows:

*Vice-president and Chairman of the Section:* W. J. Humphreys, Weather Bureau, Washington, D. C.

*Secretary:* G. W. Stewart, State University of Iowa, Iowa City, Ia.

*Member of Council:* P. G. Nutting, Kodak Research Laboratory, Rochester, N. Y.

*Sectional Committee:* Vice-president, New York, H. A. Bumstead; Vice-president, Pittsburgh, W. J. Humphreys; D. C. Miller, one year; G. W. Stewart, two years; R. R. Tatnall, three years; W. S. Franklin, four years; C. W. Waggoner, five years. *Ex-officio:* R. A. Millikan, President, American Physical Society; A. D. Cole, Secretary, American Physical Society.

*Member of General Committee:* G. F. Hull, Dartmouth College.

W. J. Humphreys,
*Secretary*