[2] The second experiment (with $t^D + t^\Delta = 30.0$ seconds and $t^D/(t^D + t^\Delta)$ decreasing from 1.00 through 0.35, 0.05, 0.03, 0.02, 0.013) is also completed (E. Hearst, "The Behavioral Effects of Some Temporally Defined Schedules of Reinforcement," unpublished Doctor's dissertation, Columbia University, 1956).

[3] Days on which a bird was not used because of a deviation greater than 15 grams from 80 per cent ad lib. weight are not included in this figure. It should be noted that the stability criterion both here and in the earlier paper was computed on the basis of uncorrected rate. Probably a better course would have been to use the corrected rate in the stability computations.

[4] Data for the initial 14 training days are not presented, nor are comparisons made with the later findings presented here, because the initial training was not continued long enough to meet our stability criterion.

[5] Cf. J. J. Boren, "Response Rate and Resistance to Extinction as Functions of the Fixed Ratio," unpublished Doctor's dissertation, Columbia University, 1953.

[6] During the 34 days taken to obtain the 30.0-second cycle recovered value given in Table 1, response rate reached a lower value (on day 26, with uncorrected rate = 66.6 responses/min, corrected rate = 73.5 responses/min) that just missed meeting the criterion, the stability computation yielding 0.0507 rather than <0.05. Thereafter, however, rate increased until the thirty-fourth day, when the stability criterion was again reached at the higher rate shown in the table.

[7] B. F. Skinner, "Superstition in the Pigeon," *J. Exptl. Psychol.*, **38**, 168–172, 1948.

[8] Cf. B. F. Skinner, *The Behavior of Organisms* (New York: D. Appleton-Century Co., 1938), pp. 123–126.

TRANSPLANTATIONS OF THE EMBRYONIC CHICK FOREBRAIN REGION BEFORE ESTABLISHMENT OF CIRCULATION

BY PETAR N. MARTINOVITCH*

OSBORN ZOÖLOGICAL LABORATORY, YALE UNIVERSITY†

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In exploring the technique involving routine decapitation of chick embryos before the establishment of circulation, *ca.* 33–36 hours of incubation, it was observed that what appeared to be primary healing took place after complete section of the nervous system in the mid-level of the mesencephalon. The embryos developed normally after healing and showed little or no effect of the section. This observation was made in the Laboratory of Development Biology at the Rockefeller Institute.

It seemed that if the chick embryo could successfully withstand this operation, it might be possible to detach completely the forebrain region of the head and then replace it in its original location as an autograft. After success had been achieved in a significant number of autografts, the technique was extended to include cross transplantations, homografts, of forebrain regions from the same breed of chicks and also from breeds different from the hosts. This report is based on 116 grafting operations, of which 40 cases were significantly successful.

The technique used in this work is quite simple, but the results showed a wide range of variation. A pair of watchmaker's forceps, adapted to the type of operation, was used for cutting through the embryonic mesencephalon. In detaching the forebrain region, care must be taken not to injure or displace the proamnion, which permits the yolk to flood the upper surface of the membrane, often causing fatality. Failure of the proamnion to fold and to undercut the embryo causes the viscera, sometimes including the heart, to remain uncovered to the last day of

incubation. If the forebrain region is removed with forceps, there is little danger of displacing the proamnion, but it is much easier to employ a suction pipette. Capillary attraction exercised by the inmoving extra-embryonic fluid provides adequate negative pressure. The tissue intended for transplantation is placed directly on the previously prepared graft bed in the host without immersion in salt solutions. This eliminates a step which, judging from observations on behavior of tissues in vitro, may be deleterious. The tissue is removed from the pipette by gentle positive pressure. It is desirable that the whole operation be completed as quickly as possible to prevent drying of the graft or the initiation of healing in the wound of the host.

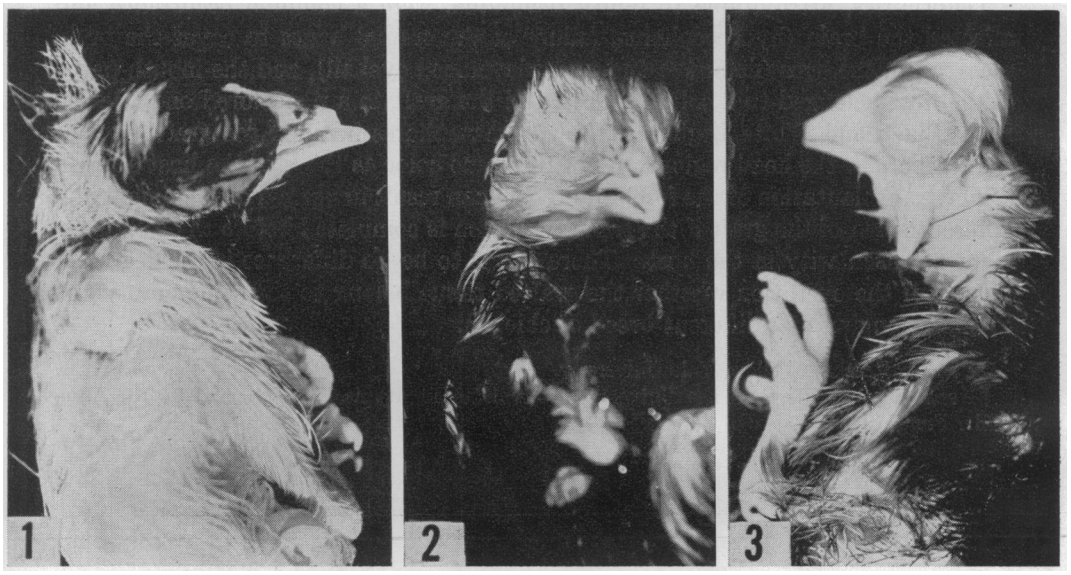

FIG. 1.—20-day-old White Leghorn embryo with grafted Barred Rock Black embryonic forebrain region Host's lower jaw longer and out of position in relation to the upper jaw that has developed from the graft. Left eye underdeveloped or, possibly, absent.

FIG. 2.—22-day-old Barred Rock Black embryo with grafted Rhode Island Red embryonic forebrain region. Mandible slightly out of position in relation to the maxilla. Black and red feathers sharply demarcated. This embryo attempted to break through the shell but failed.

FIG. 3.—20-day-old Rhode Island Red embryo with grafted White Leghorn embryonic forebrain region. Head quite normal, except for some retardation in development. The entire head including the mandible has developed from the graft. Head rotated nearly 90° in relation to a second mandible which probably originated from the host. Note a deep groove in the region of healing.

The healing process at the cut surfaces brought in apposition takes place almost immediately in autografts where apposition is more easily attained. In most instances, the line of fusion between the graft and the host tissues forms no barrier to the ingrowing blood vessels. In a few cases, there is a lag in the establishment of vascularity in the graft as compared with the host. Extravasation may occur, blood filling the forebrain vesicles; however, this is resorbed in about a week.

The results obtained depend, in the main, on the precision secured at each step of the operation. Perfect healing is obtained less frequently in homografts, where it is more difficult to secure perfect apposition of the cut surfaces of the graft and

the host tissues. The greatest trouble stems from the fact that the cut surfaces of the nerve tissues at both ends close in very quickly and heal separately, thus completely occluding the neural canal, with resultant hydrocephalus. Further growth and development of the grafted forebrain region, however, may be perfectly regular in every respect, and when the grafted embryos survive to the last day of incubation, some attempt unsuccessfully to break the shell.

Homografts were made with the same breed as the host and with different breeds. Figures 1–3 show three animals in which the host tissues are of different breeds, and indicate the degree of success so far attained. When one considers the probabilities for damage inherent to this type of work, when handling tissues of near-fluid constituency, it is remarkable that comparatively normal development ensues.

Deformities, attributable to faulty technique, were a common occurrence and affected the brain (hydrocephalus, failure of the cranial bones to cover the brain mass, etc.), the eyes (defective and underdeveloped eyeball), and the mouth parts. If the host belonged to a colored breed and the graft to a noncolored one (Barred Rock Black and White Leghorn), the chromatophores invaded the graft, so that the feathers in the head region were of the same color as those of the host animal.

The transplantation of the forebrain region can result in normal development and differentiation of the graft if the transplantation is completed before the establishment of vascularity in the host. There seems to be no difference in the degree of success of the operation whether the grafted tissue belong to the same embryo or to one belonging to a different breed of chicken.

* Sterling Research Fellow, Yale University.

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