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CHARLES H. BEST

ABSTRACTS OF COMMUNICATIONS
RÉSUMÉS DES COMMUNICATIONS

producing attacks and this probability grows with time (hunger).

(2) The multiple inputs from the retina are allowed wide opportunities for interaction with the numerous cells of the optic lobes.

(3) The characteristics of the optic lobe networks become changed by use in such manner that the situations having the attributes that have previously provided food come to produce attacks on later presentation.

(4) The attributes of situations that have produced trauma reduce the probability of attack.

(5) In an animal without vertical lobes this reduction lasts only for a few minutes.

(6) The reduction is however prolonged by repeated presentation.

(7) In an intact animal the reduction of probability of attack is prolonged by the operation of a system in which the optic output is fed at random to further sets of units (the vertical lobe system) and thence back to the optic lobes.

It is suggested that the effect of these vertical lobes in preserving the memory in the optic lobes is similar to that of re-presentation on the retina, both consisting of selection of particular patterns within the random networks.

SPERRY, R. W. (Bethesda, Maryland, U.S.A.). **Regeneration Studies and Learning.**

Earlier reports of functional readaptation following the misregeneration or deliberate crossing of peripheral nerves to foreign endorgans engendered a wide belief that the mammalian central nervous system is sufficiently plastic to adapt readily and completely to even the most drastic rearrangements of muscle action and peripheral innervation. We were told further that the central nervous readjustments responsible for this kind of learning were localizeable within the corresponding sensory or motor areas of the cerebral cortex or even within the lower spinal centers when hindlimb coordinations were involved. With respect to localization the neural basis of these habits of sensory and motor re-education stood in marked contrast to those of other habits like maze-learning, problem-box solving, perceptual discrimination and the like, the engrams of which, according to the work of Lashley and others, are notably non-localized. Thus, further analysis of the kind of learning that follows nerve regeneration and endorgan transplantation seemed to offer a particularly favorable approach to the problems of the central mechanisms of learning.

When we embarked on this project some years ago, our efforts were thwarted from the start by the repeated inability of our animals to effect any significant central reorganization in response to the surgical alterations produced in the periphery. The rearrangement of nerve-endorgan connections resulted, on the contrary, in corresponding functional disorder that tended to persist indefinitely without correction by re-education. For example: rats with painful trophic sores on their right hind foot would hop about on 3 legs protectively holding up their uninjured left leg — and thus placing extra weight on the inflamed right foot — because the sensory nerves had earlier been crossed from left to right foot. This perverse behavior continued uncorrected throughout the waking day for 6 to 9 weeks until eventually the excessively aggravated ulcers healed, or the animal died. Rats with flexor and extensor nerves of the leg interchanged a few weeks after birth would go through the remainder of their lives making all foot movements in reverse. Frogs or newts with their eyes surgically rotated 180 degrees in larval stages continued to respond thereafter as if the visual field appeared to be upside down. Monkeys, with the nerve supply of the brachial biceps and triceps muscles interchanged, learned quickly to inhibit the resultant reversal of elbow movement, but failed in a period of 3 years to effect a generalized positive correction of the reversed muscle action. Application of conditioning techniques and other special training measures have failed to bring about readaptation of these and similar types of functional disorder.

A critical revaluation of the older studies undertaken in the light of these conflicting results has since disclosed that in nearly all cases, the earlier optimistic interpretations are suspect. In many instances, it is quite obvious that other factors such as vicarious muscle function, anomalous innervation, two-joint tendon action, and the like, were mistaken for reorganization in the central circuits of the nerves involved.

Subsequent analysis of functional recovery following peripheral nerve regeneration in both clinical and in experimental studies has tended in recent years to confirm this conclusion and is leading generally now to a much more conservative estimate of central nervous plasticity than was prevalent 15 years ago.

Meanwhile, investigations of another sort dealing with regeneration of synaptic connections within the central nervous system in lower vertebrates have yielded supporting results with implications entirely in harmony with the foregoing. Regeneration of the optic, vestibular, trigeminal, and spinal sensory roots and also of the tecto-spinal and other intracentral tracts has been found to result in each case in an orderly reestablishment of the central reflex relations of the various classes of constituent fibers. This occurs despite the chaotic intermixing of the individual fibers in the course of their regeneration into the centers and despite various surgical alterations that render the functional effects of the synaptic patterning extremely maladaptive for the organism. In addition to confirming further the implastic nature of much of the basic, genetic structuring of the nervous system, the work on synaptic formation begins to suggest something about the possible nature of the regulative factors responsible for the orderly prefunctional patterning of the neural circuits during growth. These notions concerning the genesis of innate behavior patterns in turn have implications regarding possible bases of learned behavior.

The results of the combined studies on peripheral and central nerve regeneration have come to acquire meaning for the learning problem very different from what was expected at the outset. In the main their contribution lies more in a disclosure of some of the limitations and other negative aspects of the learning process than upon any direct delineation of its positive features.

Following are some of the concepts regarding the physiology of learning that have found support, direct or indirect, in nerve regeneration studies:

a) Reeducation adjustment after rearrangement of peripheral nerves or their endorgans does not, contrary to earlier indications, represent a special kind or extreme of learning in which the central mechanisms are radically more primitive or more localized than are those of ordinary sensory and motor learning. The limits of central dissociation and reorganization are essentially of the same order as under normal conditions.

b) The organization of large portions of the nervous system is predetermined by genetic forces and is not subject to readjustment by learning. This applies to the afferent and efferent pathways and to much of the spinal and brain stem integration. The input and output channels and many other basic integrative mechanisms must be used in common for large categories of activity. To adapt them for one performance would spoil them for others.

c) The new adaptations of motor behavior achieved by learning do not involve any detailed restructuring of the basic motor organization but only a recombination of the genetic elements of organization in new temporal and spatial patterns.

d) The increase in capacity for motor learning seen in the higher mammals is accompanied by an increased differentiation of the innate organization that permits dissociation and recombination of the genetic motor components of behavior in finer and finer degree. The evolutionary elaboration of the corticospinal system permits increasing refinement in the higher level control of motor activity.

e) Any learned performance involves large components of unlearned neural organization. With the possible exception of man, the genetic components are generally the more complex and precisely organized from the physiological standpoint.

f) Learning in general is not to be regarded merely as a product of the passive plasticity of nervous tissue or of neuronal cytoplasm as such. Learning involves the operation of a highly organized mechanism precisely designed to select and actively to retain and use particular effects of particular past experiences.

g) The neural traces or engrams of learned activity will not be found to reflect in any detailed or direct manner the patterning of the learned behavior — whether this be sensory, motor, or associational in character. In addition to the innate components mentioned above, learned activities involve background attitudes, sets, or postures of transient, dynamic organization which are directly responsible for patterning the learned behavior and in terms of which any permanent static traces must gain their expression.

h) Discovery tomorrow of the cytological or biochemical nature of the engram (such as change in synaptic resistance, growth of new fiber connections, etc.) would leave unanswered most of the current problems of learning physiology. These remain largely organizational in character and concern the patterning of the engram with reference to that of the reactivating process on the other.

With the foregoing as a background, some of the above and related topics will be presented for discussion at the symposium.

Bykov, K. M. (Leningrad, U.S.S.R.). **New Data on the Physiology and Pathology of the Cerebral Cortex.**