PHYSIOLOGY

THE REPRESENTATION OF THE INTERNAL ORGANS IN THE CEREBRAL CORTEX AND CEREBELLUM OF CATS AND DOGS

COMMUNICATION I. REPRESENTATION OF THE PELVIC NERVE IN THE CEREBRAL CORTEX OF CATS

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The problem of the interconnection of the cerebral cortex with the internal organs began to attract the attention of investigators in the latter third of the 19th century. One of the first pieces of work in this direction was accomplished by V. Y. Danilevsky [7], who showed in 1874 that irritation of definite portions of the cerebral cortex with an electric current produces in dogs a change in cardiac activity and in the state of the vascular system.

In the subsequent work of L. Bochefontaine [27], V. M. Bekhterev and N. A. Mislavsky [3], V. M. Bekhterev and coworkers [2], A. Cherevkov [23], B. Babkin and T. Speakman [26], B. Kaada [33] and others it was shown that in the cortex of the cerebral hemispheres of different animals a number of zones can be distinguished, the irritation of which exerts an influence on the activity of certain of the internal organs. Subsequently, work was carried out in this direction through use of the method of extirpation of different portions of the cerebral cortex and the conditioned reflex method [1, 5, 6, 10, 11, 16, 17, 20, 22 et al).

By this work and, primarily, by the numerous investigations of the academician K. M. Bykov and his school, bilateral connections were conclusively demonstrated existing between the internal organs and the cerebral cortex, and the influence of the cerebral cortex on the work of the internal organs was established.

Electrophysiological investigations occupy a chief place in the history of the problem.

Studies of the bioelectric manifestations in the brain during irritation of the nerves of the internal organs, the first of which were performed in 1891 by V. Y. Danilevsky [8], with the development of the technique of recording biocurrents led to the appearance of a number of works devoted to clarifying the influence on the cortex of irritating the internal organs and partially innervating their nerves. From the work of F. M. Lisitsa [13], E. S. Tolmasskaya [21], V. E. Delov [9], P. O. Makarov [14], F. N. Serkov [19], N. V. Bratus [4], T. E. Orlova [15] et al., it is apparent that following irritation of the internal organs diffusion changes produce the electrical activity of the cerebral cortex. In addition, in spite of the inconsistency of the data, the majority of the investigators consider that the premotor zone of the cortex has the predominant relationship to the internal organs. To put forward more definite conclusions on the basis of the facts obtained with the method indicated is not possible.

Particular attention is due the electrophysiological investigations which have been developed abroad in recent years on the primary bioelectrical reaction arising in the cerebral cortex in response to irritation of a particular nerve carrying afferent fibers from the internal organs.

By this method P. Dell and P. Olson [31] made more precise the data of P. Bailey and F. Bremer [28] relative to the cortical representation of the vagus nerve and discovered the organization of its specific and nonspecific central projections. H. D. Patton and V. E. Amassian [35] described the cortical projections of the tympanic nerve, and M. Bonvallet, P. Dell, A. Hugellin and B. Weil [29] did the same for the projections of the lingual nerve. V. E. Amassian [25], C. B. B. Downman [32] and P. P. Newman [34] detected a strictly limited zone of representation in the cortex of the afferent fibers of the celiac nerve (Fig. 1).

At the suggestion of Prof. V. N. Chernigovsky we made use of the evident advantages of the method of recording the primary responses in order to collect additional material on the representation in the cerebral cortex of the afferent system of the internal organs and, primarily, to elucidate the cortical projections of the pelvic nerve.

The choice of this nerve is explained by the fact that up until the present its cortical representation has not been shown, although it is a known fact that the nerve contains a large number of afferent fibers from the organs of the lesser pelvis.

EXPERIMENTAL METHODS

The experiments were conducted on 40 cats. The animals, which were under ether narcosis, were tied to a board, after which they were injected intravenously with chloralose or Nembutal. Generally an experiment was begun under superficial anesthesia which later, depending on the purpose of the experiment, was increased to the desired extent. The central endings of the pelvic nerves were placed on submersion electrodes,* and, in a number of experiments the nerve which was on the electrodes prior to their submersion into the cavity of the lesser pelvis was perfused with neutral mineral oil at a temperature of 38° through which oxygen had previously been passed. Then a wide opening was made in the cranium, and the dura mater was removed.

In all of the experiments the shunting of the biopotentials of the cortex was unipolar. In a number of cases a localizing electrode was fastened to a manipulator which provided for a precision of up to 0.5 mm in shifting it over the surface of the cortex. The shunting was accomplished by means of cotton-paper filters soaked in Locke-Ringer's solution, tightly wound around chlorinated silver wires. In some experiments electrodes were used consisting of a silver wire suspended on a watch spring with a spheroid thickening at the end. The latter method provided the greatest certainty, inasmuch as the magnitude of the potential being shunted did not depend on a change of contact and degree of moisture of the filter.

Indifferent electrodes in the form of heavy steel needles were fastened in the bone of the cranium above the frontal sinuses. The animal was grounded and was kept warm throughout the experiment by means of a screened electric heater; the rectal temperature was recorded. In order to protect the brain cortex from chilling, it was kept warm by means of a screened heat lamp with an automatic thermoregulator and moistened with Locke-Ringer's solution heated to 38°. The experiments were conducted in an insulated room. Irritation of the central ending of the pelvic nerve was accomplished with single shocks of current from a condenser stimulator or with rectangular stimuli lasting 0.1-0.2 milliseconds from an electronic stimulator. The biopotentials of the cortex following a corresponding boost of the transformed current with capacity rheostat boosters, assembled according to a balance scheme, were conveyed to oscillographic electron-ray tubes. From the latter a photorecording was made on motion picture film. The curve of the boosters was linear within 5 to 300 cycles/sec.

EXPERIMENTAL RESULTS

The experiments showed the presence in cats in each cerebral hemisphere of two independent cortical zones for the visceral nerves, not corresponding with any of those detected earlier, in which primary responses arise during irritation of the central ending of n. pelvicus (see Fig. 1). In the present communication we shall describe the zones of the specific projections of the indicated nerve and shall not give, because of the size of the article, a detailed comparative characterization of the primary responses which were recorded in them.

* The submersion electrodes were a modified version of the electrodes suggested by P. Kiselev in the laboratory of electrophysiology of the I. P. Pavlov Institute of Physiology.

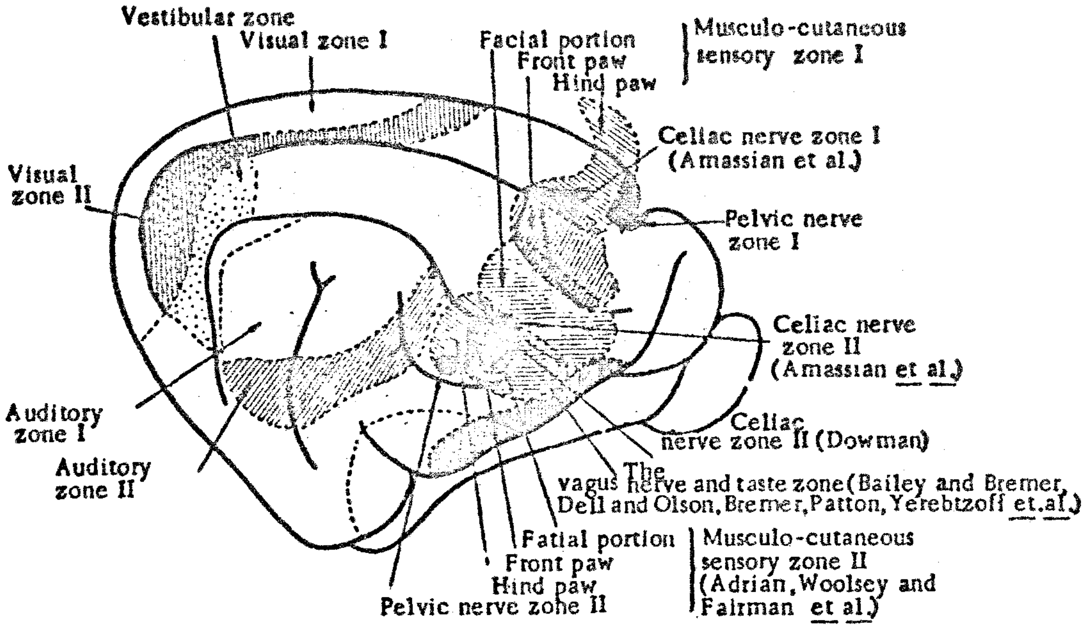

Fig. 1. Scheme of the location in the cerebral cortex of the cat of representation of different afferent systems. The map composed by P. Dell served as a basic scheme, altered and supplemented according to the data of a number of authors.

As is well known, the primary response is considered the direct bioelectric reaction of the cerebral cortex in response to irritation of receptors or afferent nerves. The principal sign characterizing this reaction is the extent of the latent period, which is subject to certain fluctuations, but which is minimal in comparison with the extent of the latent periods of the accompanying secondary reactions. In addition the primary response has a definite direction of fluctuation of potential and a characteristic duration. It is recorded only in those zones of the cortex in which are located the cells in which terminate the corresponding afferent pathways that pass through the differentiated sensory nuclei of the thalamus.*

The first of the described zones of the pelvic nerve is located on both sides of the medial and intermediate part of the sulcus cruciatus (Fig. 2). In this region the "focus of maximal activity" is located on the anterior part of the gyrus cruciatus posterior along the sulcus cruciatus, including slightly the neighboring posterior part of the gyrus cruciatus anterior. The second zone of cortical representation of the pelvic nerve is located on the gyrus ectosylvius anterior, occupying the small space along the inferior and middle part of the sulcus ectosylvius anterior (Fig. 3). In both zones when the shunting electrode is moved to the side of the focus of maximal activity the amplitude of the primary response decreases, while its latent period increases. The dimensions of the zones as well as the value of the amplitudes of the primary responses recorded in them depend on a number of circumstances. When the strength of the irritating current is augmented, the value of the amplitude of the response increases, quite rapidly attaining a maximal value; after this a further increase in current strength no longer produces an increase in amplitude. Under these conditions the boundaries of the zones of representation of the nerve under consideration are extended. With threshold values of the irritation current, the size of the zones and the amplitude of the responses depend upon the extent of narcosis, the condition of the animal and the functional state of the cerebral cortex. Increasing the narcosis leads to a reduction of the zones of representation and to a certain decrease in the amplitude of responses. Chilling the animal, low blood pressure, asphyxia, and chilling or overheating the cerebral cortex lead initially to a reduction of the zones of representation and a decrease in the amplitude value of the responses, and then to their full disappearance. In our experiments the size of the first zone was about 12 mm^2 with reasonably deep anesthesis in which the "spontaneous" activity of the cortex was depressed, while the focus of maximal activity was considerably less. Under the same conditions the area

* For detailed data on this question see A. I. Roitbak [18].

of the second zone did not exceed 8 mm^2. With a further increase in narcosis, for example, in the experiment the results of which appear in Fig. 3, the primary responses recorded around the focus of maximal activity (A and B) ceased to appear and a primary reaction in the form of a positive fluctuation in potential was preserved only in the spots where prior to this the responses had the greatest amplitude.

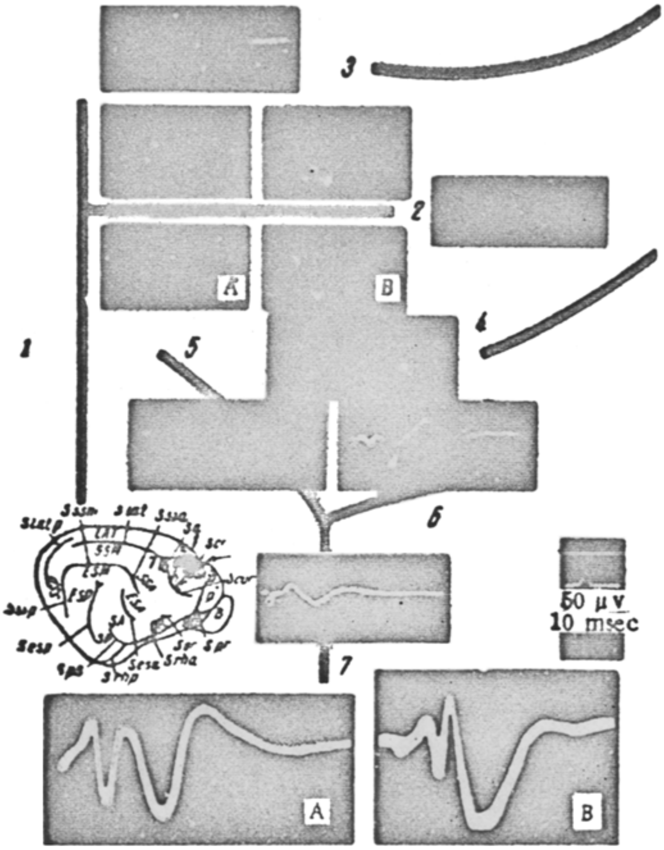

Fig. 2. Scheme of the distribution of primary responses in the right contralateral zone I of the cerebral cortex. Cat No. 85; December 9, 1955. Chloralose narcosis. Initial dose – 100 mg/kg body weight. The animal was immobilized by intravenous injection of Diplacine, 0.5 cc of a 2% solution per kg of body weight. Artificial respiration. The central ending of the left pelvic nerve was irritated. A single shock of current at a voltage of 5 v served as the stimulus. The records are read from left to right. The deflection of the recorded beam downward corresponds to a positive fluctuation of potential.

1) fis. longitudinalis cer; 2) s. cruciatus; 3) s praesylvius; 4) s. coronalis; 5) s. ansatus; 6, 7) s. lateralis. On the diagram of the cerebral cortex, zone I of the cortical representation of the pelvic nerve is indicated by (↑).

When the stimulation is applied to the central ending of one of the pelvic nerves, primary responses arise in four portions of the cortex: in the two zones indicated of the contralateral (with respect to the nerve irritated) hemisphere and in the corresponding two zones of the homolateral hemisphere.

In control experiments on animals immobilized by intravenous injection of Diplacine it was established that the responses recorded do not appear as a result of possible contractions of somatic muscles. The proximity of the second zone of the pelvic nerve to the acoustic region necessitated the elimination of audible stimuli, and this we accomplished. In a number of experiments for control purposes the pelvic neve was crushed above the applied electrodes; this completely eliminated the emergence of primary responses. The use of a cold block exerted the same effect, and after its removal primary responses were again recorded.

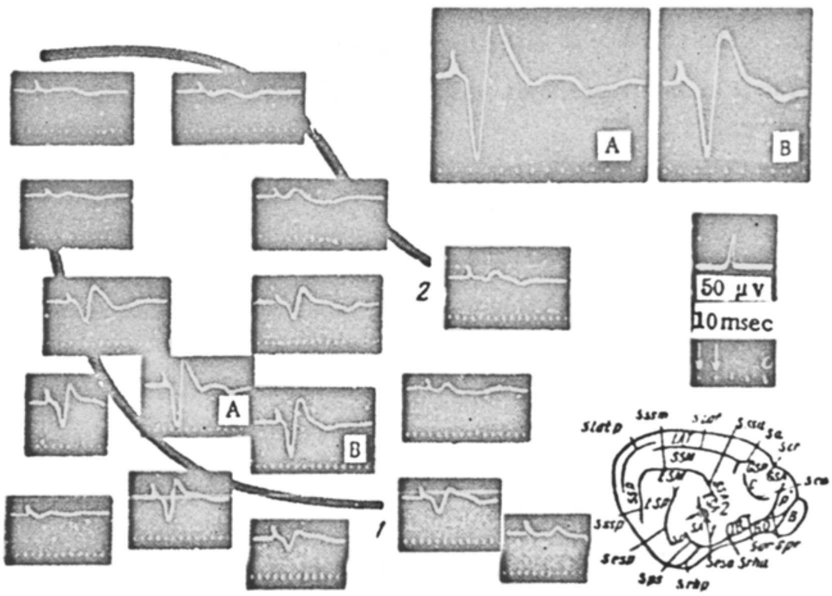

Fig. 3. Scheme of the distribution of primary responses in the right contralateral zone II of the cerebral cortex. The continuation of the experiment the beginning of which is recorded in Figure 2. The central ending of the left pelvic nerve was irritated with single shocks of current at a voltage of 4.4 v. The other conditions of conducting the experiment the same.
1) s. ectosylvius ant; 2) s. suprasylvius ant. On the diagram of the cerebral cortex, zone II of the cortical representation of the pelvic nerve is indicated by (↑), and the solid spot represents the "focus of maximal activity" (A and B).

CONCLUSIONS

The results of the work conducted afford an opportunity to consider once again a problem which still remains quite unclear—that of the structure of an internal analysor. In this question no one opinion yet prevails. Thus, for example, E. S. Airapetyants considers highly improbable the existence in the cerebral cortex of "specially defined, strictly localized portions" for an internal analysor [1], while V. N. Chernigovsky thinks that "zones of cortical representation may actually be regarded as nuclei of an analysor" [24]. While maintaining the latter opinion, we would point out that evidently the nucleus of an internal analysor has a complex structure: territorially represented in a number of zones of the cortex, within the limits of each zone it is composed of a number of "foci of maximal acitivity," corresponding to cortical projections of visceral afferent pathways.

The presence in the cortex of defined and definitely localized portions for the nucleus of an internal analysor in no measure diminishes the principle of dynamic localization of function, provided "dynamics" is taken to mean the functional interaction of processes within the limits of a single analysor (although adapted to a definite territory) and their interconnection with like processes in other analysors.

SUMMARY

Data about the localization in the cerebral cortex of cats of afferent zones of representation of the pelvic nerve are described for the first time. Single electric stimuli of the central ending of the pelvic nerve have revealed in the cerebral cortex two zones registering primary responses of maximum amplitude and minimum latent period.

Zone I is localized on both sides of the medial and intermediate parts of s. cruciatus. Zone II is situated on g. ectosylvius ant., occupying a small space along the lower and middle parts of s. ectosylvius ant. The area of Zone I is about 12 mm^2 and Zone II about 8 mm^2.

Both of these areas are bilateral, and stimulation of the pelvic nerve elicits a primary reaction in four portions of the cortex: in contralateral Zones I and II and in the corresponding ipsilateral Zones I and II.

LITERATURE CITED

[1] E. S. Airapetyants, Zhur. Vysshei Nerv. Deyatel., Vol.5, No. 5, p. 644 (1955).

[2] V. M. Bekhterev, in the book: Transactions of the St. Petersburg Clinic of Mental and Nervous Diseases,* Vol. 1, 699 (1906).

[3] V. M. Bekhterev and N. A. Mislavsky, Records of Psychiatry, Neurology and Legal Psychiatry, Vol. XII, Part 2, p. 75 (1888).

[4] N. V. Bratus, Fiziol. Zhur. SSSR, Vol. 52, No. 2, p. 232 (1956).

[5] I. A. Bulygin, in the book: Neurohumoral Regulation of the Activity of the Digestive Apparatus,* p. 110, Moscow (1949).

[6] K. M. Bykov, The Cerebral Cortex and the Internal Organs,* State Medical Press (1947).

[7] V. Y. Danilevsky, Investigations of the Physiology of the Brain,* (1876).

[8] V. Y. Danilevsky, in the book: The First Native Electroencephalographic Investigations,* p. 77, State Medical Press (1949).

[9] V. E. Delov, Trudy Voenno-Morsk. Med. Akad., 17, 117 (1949).

[10] K. A. Dryagin, Trudy Kazan. gos. Med. Inst. No. 1-2, Kazan (1939).

[11] A. L. Komendantova, in the book: Abstracts of Five Conferences on Physiological Problems,* Moscow (1932).

[12] K. M. Kullanda, in the book: Abstracts of Reports Presented at the Conference of Young Scientists of the Institute of Normal and Pathological Physiology of the Academy of Medical Sciences of the USSR, May 28, 1956,* pp. 24-25.

[13] F. M. Lisitsa, Byull. Eksptl. Biol. i Med., No. 5-6, 12, 261 (1941).

[14] P. O. Makarov, Fiziol. Zhur. SSSR, Vol. 38, No. 3, p. 281 (1952).

[15] T. E. Orlova, Notes for a Dissertation,* Odessa (1956).

[16] V. G. Prokopenko, Abstracts of Reports from Five Conferences on Physiological Problems,* p. 70, Moscow (1939).

[17] N. F. Popov, An Investigation of the Physiology of the Cerebral Cortex of Animals,* Moscow (1953).

[18] A. I. Roitbak, Bioelectric Phenomena in the Cortex of the Cerebral Hemispheres,* Part I, Tbilisi (1955).

[19] F. N. Serkov, in the book: Higher Nervous Activity and Corticovisceral Interrelationships,* p. 68, Kiev (1955).

[20] A. N. Sovetov, Dissertation,* Moscow (1954).

[21] E. S. Tolmasskaya, Byull. Ekspti. Biol. i Med., Vol. 26, Part 6, No. 12, 413.

[22] M. A. Usievich, Zhur. Vysshei Nerv. Deyatel., Vol. 1, No. 1, p. 1 (1951).

[23] A. Cherevkov, The Influence of the Cerebral Hemispheres of the Brain on the Heart and Vascular System,* Kharkov (1892).

[24] V. N. Chernigovsky, Zhur. Vysshei Nerv. Deyatel., Vol. 6, No. 1, p. 53 (1956); In the book: Abstracts of the Reports of 17 Conferences on Problems of Higher Nervous Activity,* pp. 142, 26-28, Leningrad (1956).

* In Russian.

[25] V. E. Amassian, Federation Proc. 9, 5, 1950; J. Neurophysiol., 1951, Vol. 14, p. 433, 445.

[26] B. P. Babkin and T. J. Speakman, J. Neurophysiol., 1950, Vol. 13, p. 55.

[27] L. Bochefontaine, Gaz. Medical du Paris, 1875, Arch. de Physiol. norm. and pathol., Vol. 3, Series 12, p. 164, Paris, 1876.

[28] P. Bailey and F. Bremer, J. Neurophysiol., 1938, N. 1, p. 405.

[29] M. Bonvallet, P. Dell, A. Hugellin and B. Well, Quoted according to Dell (30).

[30] P. Dell, J. Physiol., 1952, Vol. 44, p. 471.

[31] P. Dell and P. Olson, Societe de Biologie, 145, 13-14, p. 1084, Paris, 1951.

[32] C.B.B. Downman, J. Physiol., London, 1951, Vol. 113, p. 434.

[33] B. R. Kaada, Acta Physiol. Scand., 24, Suppl., 83, p. 1259, 1951.

[34] P. P. Newman, J. Physiol., 1952, Vol. 116, N. 1, p. 8.

[35] H. D. Patton and V. E. Amassian, J. Neurophysiol., 1952, Vol. 15, p. 245.