

THE FUNCTIONAL SIGNIFICANCE OF CERTAIN DUPLICATE MOTOR PATTERNS ON THE CEREBRAL CORTEX IN PRIMATES INCLUDING MAN

Elizabeth C. Crosby↓* and *James R. Augustine**

Submitted in honor of Prof. Dr. J. Drooglever Fortuyn on the occasion of his 70th birthday and retirement from active work at the University of Groningen.

SUMMARY

Rotation elicitable from direct irritation or implantation of the cortical irritant, penicillin, in both rostral and posterior parts of the temporal operculum and on the island cortex in the monkey (*Macaca mulatta*) has been described and illustrated in photographs. The pathways to and from these temporal and island areas have been considered and the results obtained have been compared with related reports in the literature on rotation in monkeys and man. The probably role of the precentral and postcentral insular areas and their related paths to the contraction of the muscles (sometimes called the agonists) on the side of an extremity in the direction of movement of that extremity and the commensurate relaxation of the muscles (sometimes called the antagonists) cooperating with them on the other side of the extremity is discussed.

CERTAIN BASIC FACTS PERTINENT TO THIS RESEARCH PROJECT

By irritative and/or destructive lesions rotational movements have been elicited from various subcortical levels of the primate brain such as the lingula of the cerebellum in its relation to the anterior medullary velum (CROSBY, TAREN and DAVIS, 1970) and by removal of cerebellar areas (FULTON and CONNOR, 1939). These will not be considered in the present paper.

Rotational movements have been reported by various observers from implantation of penicillin-filled capsules on frontal, parietal and potential insular cortical areas of various mammals from opossum to monkey. A recent resumé of these experiments is to be found in an abstract by HAMEL, BROWN, CAPRA, KINNEY, ROMFH and AUGUSTINE (1975). Circling movements following removal of the frontal cortex have been seen repeatedly in monkeys (KENNARD and ECTORS, 1938; CROSBY, SCHNEIDER, DE JONGE, and SZÖNYI, 1966; and many others).

Implantation of discs containing alumina cream produced circling in a counter-clockwise direction in monkeys when the discs were placed on the left inferior frontal gyrus. Backward somersaulting resulted when the discs were embedded on

↓* Department of Surgery, Section of Neurosurgery, University of Michigan Medical Center, Ann Arbor, Michigan, U.S.A.

* Department of Anatomy, University of Alabama in Birmingham, The Medical Center, Birmingham, Alabama U.S.A.

the surface of the rostral end of the superior temporal gyrus (CALHOUN and CROSBY, 1965; CROSBY and CALHOUN, 1965). Rotational movements have been reported following irritation of the island cortex along the two sides of the central insular fissure (CROSBY, 1975).

PENFIELD and RASMUSSEN (1950) called attention to two groups of patients who had subjective feelings of disorientation with reference to their surroundings. Patients with lesions on the inferior lip of the intraparietal fissure complained that the world was rotating around them. Others with lesions in the temporal cortex, not far from auditory cortex, felt that they were rotating in space, although they did not actually turn. There are also reports of the actual occurrence of rotation in man. A few patients with lesions in the rostral end of the temporal lobe and with preoperative signs of psychomotor epilepsy or with operative evidence of the site of the lesion (opercular area, SCHNEIDER, CALHOUN and CROSBY, 1968; frontotemporal lesions, SCHNEIDER, CALHOUN and KOOI, 1971; opercular region of superior temporal gyrus, MAXWELL, 1974) have shown actual rotation. Rotation was also seen from an island lesion in a patient operated upon by FLEMING (personal communication).

Rotation appears to be a sign of imbalance in discharges from the two sides of the brain and represents an attempt to maintain equilibrium and orientation in space. Presumably areas from which rotation can be obtained are activated by the projection of impulses to them from receptive visual, vestibular, tactile and auditory cortices. A further study of these cortical areas from which rotation can be produced in macaques appears justified because of their interesting character experimentally and their possible value in clinical diagnoses.

EXPERIMENTAL STUDIES*

(A) *Methods and Materials*

All these experiments were carried out by the use of very careful sterile technique and under ketamine anesthesia. Before the cortical irritant was implanted, the presence of a supplementary motor pattern was established on the cortical areas

* The first experiment in this series, using Monkey 3063, was performed February 18, 1975 in the Neurosurgical Research Laboratory, University of Michigan Medical Center, Ann Arbor by DR. HARRIS RUSSO, DR. CROSBY and MR. ELWYN GOODING. The experiment had been undertaken to document the earlier demonstrated extrapyramidal patterns on the precentral and postcentral insular cortices.

The remaining experiments were carried out in the Department of Anatomy at the University of Alabama in Birmingham by the authors of this paper. They are grateful to MRS. LUCILLE HILL for serving as operating room technician during the experiments.

The monkeys used for these experiments at the University of Alabama were provided through the generosity of DR. LEON SCHMIDT of the Southern Research Institute. The authors are greatly indebted to DR. SCHMIDT, without whose help it would have been very difficult, and perhaps impossible, to carry out this series of experiments at this time.

to be studied by electrical stimulation except for the cortex on the opercular surface of the superior temporal gyrus (Monkey 8536).

Small discs filled with sterile procaine penicillin G suspension (Wyeth) were employed as the stimulant or irritant in these experiments. Such discs were placed firmly against the exposed cortex, often several of them being used to cover a single field.

(B) *Protocols*

Monkey 3063 (male – weight 5 kg.)

February 18, 1975, following a left temporoparietal craniectomy and removal of the dura, the parietal opercular area behind the postcentral gyrus was partly removed by suction and the insula revealed. In the monkey, a distinct central insular fissure separating the precentral and postcentral insular fields cannot be identified. This central insular fissure is present in man and provides a distinct boundary between the precentral and postcentral insular cortices. Stimulation procedures indicate the presence in the monkey of a precentral and a postcentral insular field which were brought to view by further removal of opercular cortices and by retraction. Only the extreme posterodorsal and anteroventral regions of the insula were not available for stimulation.

On stimulation of the exposed island, using 4-6 volts at 50 pulses per second, the pattern indicated in Figure 1 was documented except for the homolateral face movements, which could not be obtained with the most anteroventral part of the island unexposed. The operative site was closed with the usual aseptic precautions (although the dura could not be sutured) and the animal was placed in an observation cage. At the close of the operation, from repeated stimulation, the precentral and postcentral insular area appeared to be irritated.

The animal began to recover shortly after his removal to the cage and, in about half an hour after the conclusion of the experiment, was able to stand and walk. He then developed postoperative seizures. During such a seizure he appeared to become dazed, walked slowly half way across the cage and then circled slowly, in a clockwise fashion, two or three times. After circling, he lost the dazed appearance and returned to his former place at the opposite corner. This circling, which gradually decreased in frequency, disappeared in about 36 hours, after which the animal appeared to regain his normal behavior. This circling has been reported by CROSBY (1975).

Monkey 873 (female – weight 4.5 kg.)

On March 31, 1975 a left parietotemporal craniectomy was carried out, the dura excised and the parietal operculum and the posterior part of the temporal operculum were exposed. One half cubic centimeter of penicillin was injected into the parietal cortex posterior to the postcentral insular area and dorsal to the lateral fissure. The dura was sutured and the operative site closed with the usual

precautions. The animal recovered readily from the anesthetic. He showed no overt effects of the operation.

On May 7, 1975, the animal was reoperated. A right parietotemporal craniectomy was performed, the dura retracted and the parietal opercular area, posterior to the postcentral gyrus, was removed, exposing the insula. A typical extrapyramidal pattern for extremity and body movements, similar to that illustrated in Figure 2, was obtained on stimulation at 4-6 volts, 50 pulses per second and 1 millisecond duration. One large penicillin-filled capsule was placed over the area from which upper extremity movements had been obtained on stimulation, the dura partially sutured and the operative site closed in the usual fashion.

On recovery from the anesthetic the animal had seizures involving the face and upper limb on the left. The animal did not rotate.

On May 9, the right insular region was re-exposed, the location of the penicillin capsule verified and the capsule was removed. Then two capsules freshly filled with penicillin were placed along both the precentral and the postcentral insular areas over the region from which homolateral and contralateral upper and lower extremity movements had been elicited during stimulation on May 7. The dura was laid over the capsules and the operative site closed carefully.

After recovery from the anesthesia the animal had a series of motor seizures. During each seizure he stared as if unaware of his surroundings, then walked slowly toward the other side of the observation cage but, when about two thirds of the distance across the cage, rotated slowly several times in a counterclockwise direction (Figure 2). After the rotation, he again became aware once more of his surroundings. This pattern was repeated at every seizure but between seizures the animal appeared normal.

Initially, the seizures were so frequent (about 10 minutes apart) that the animal gradually grew very tired. To give him some relief, small doses of Dilantin were finally administered. As its effects wore off, the seizures returned. By the end of the second day after the last operation, the seizures had decreased in frequency. They had disappeared by the end of the third day and the behavior of the monkey appeared normal. After recovery from this series of experiments the animal was used by another observer for a quite unrelated study.

Monkey 8111 (male - 500 grams)

On May 7, 1975 a right temporoparietal craniectomy was performed and the dura retracted to expose the posterior part of the superior temporal gyrus. Stimulation at 4-5 volt, 50 pulses per second and 1 millisecond duration revealed the typical extrapyramidal motor pattern. A large penicillin capsule was implanted over the upper extremity area, the dura replaced and fastened loosely over the capsule, and the wound closed in the usual manner.

As this squirrel monkey began to arouse from the effects of the anesthetic he showed a severe seizure pattern rolling over and over toward the right side. Because of the violent nature and persistence of these seizures on the first post-operative day, the animal was given a small dose of Dilantin. The seizures persisted

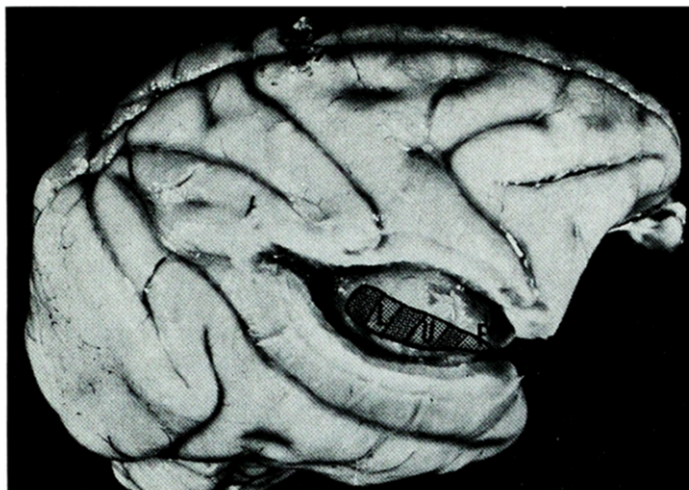


Figure 1. Photograph of the lateral surface of the macaque brain. The island is exposed and the motor pattern on it illustrated. The lighter shaded segments of the pattern represent the fields from which homolateral responses were obtained and the adjacent darker shaded segments represent fields from which contralateral responses were obtained. F=face; U= upper limb; L=lower limb.

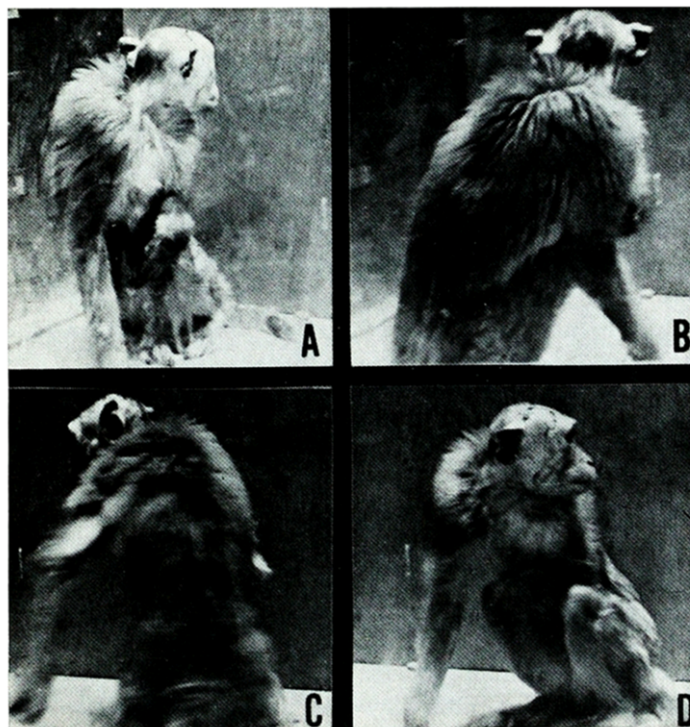


Figure 2. Photographs in an A-D sequence illustrating rotational movements of monkey 873 resulting from implantation of penicillin in the island region.

into the third postoperative day, although diminished in frequency and violence. After the seizures ceased, the animal recovered rapidly.

The animal was sacrificed by perfusion-fixation on May 21, 1975 and the location of the empty capsule verified. The brain was removed for later study. Monkey 8536 (female - 4.2 kg.)

On September 11, 1975, following a left parietotemporal craniectomy and retraction of the dura, the parietal cortex dorsal to the lateral fissure and posterior to the postcentral area was exposed and stimulated. A portion of the extrapyramidal pattern illustrated in Figure 3 was demonstrated. Four capsules containing penicillin were implanted along this extrapyramidal field covering essentially all the area of the parietal lobe from which movements had been obtained on stimulation.

On recovery from the anesthetic the animal showed a series of seizures consisting of somewhat bizarre movements of the right extremities, that is, those contralateral to the irritated cortex. These movements persisted for 2 days and then disappeared after which the animal's behavior became apparently normal.

On September 17, 1975 the parietal cortex dorsal to the lateral fissure was exposed on the left by a parietotemporal craniectomy followed by retraction of the dura. The area was stimulated and a pattern for contralateral head, extremities, trunk and face movements was established (Figure 3). The tail assumed a vertical position. Three penicillin capsules were placed over the more ventral portion of the parietal cortex. Following recovery from the anesthetic a series of contralateral seizures involving head, face and upper extremity appeared (Figure 4). The contralateral lower extremity was not involved in these movements. The seizures persisted for about three days. After they ceased, the overt behavior of the animal appeared normal.

On October 3, 1975, on re-exposing the left parietal cortex, the three capsules previously implanted on September 17 were now empty. They were removed and replaced by three freshly filled capsules which occupied the previous area of capsule implantation. A fourth capsule was placed farther posteriorly to involve the region which had given lower extremity responses during stimulation carried out on September 11. As the animal recovered from the ketamine anesthesia, seizures appeared, involving head, trunk and tail and upper and lower extremities on the right. These seizures were very pronounced and, during them, the animal was unable to stand. He showed no tendency to rotate and no evidence of seizures on the side of the operation.

On October 14, 1975 a fourth experiment was performed on this monkey. The wound was reopened and three penicillin-filled capsules were implanted on the posterior part of the left temporal gyrus. The animal showed hemirotation involving the head, upper extremity and trunk with the head leading in the hemirotation. This response persisted for about three days and then the animal showed no marked behavioral defects except that, with so much cortex injured, she was somewhat obtunded.

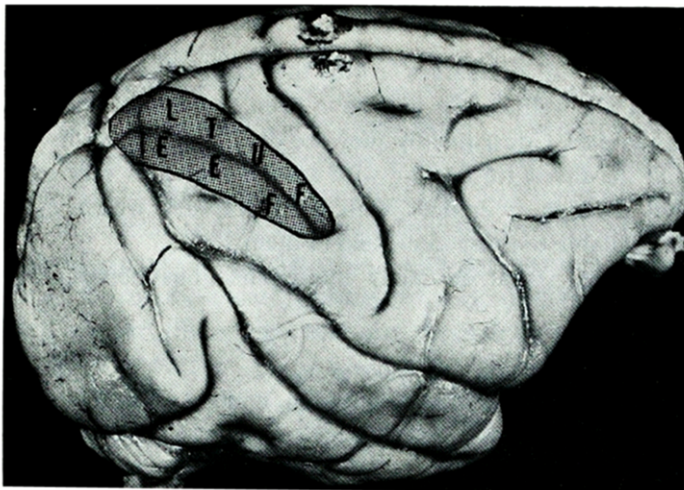


Figure 3. Photograph of the lateral surface of the macaque brain. The region of electrical stimulation and implantation of penicillin on the parietal cortex of monkey 8536 is shaded. The extrapyramidal (additional) motor pattern obtained from this area is indicated. F=face; E=eye deviations; U=upper limb; T=trunk; and L=lower limb.

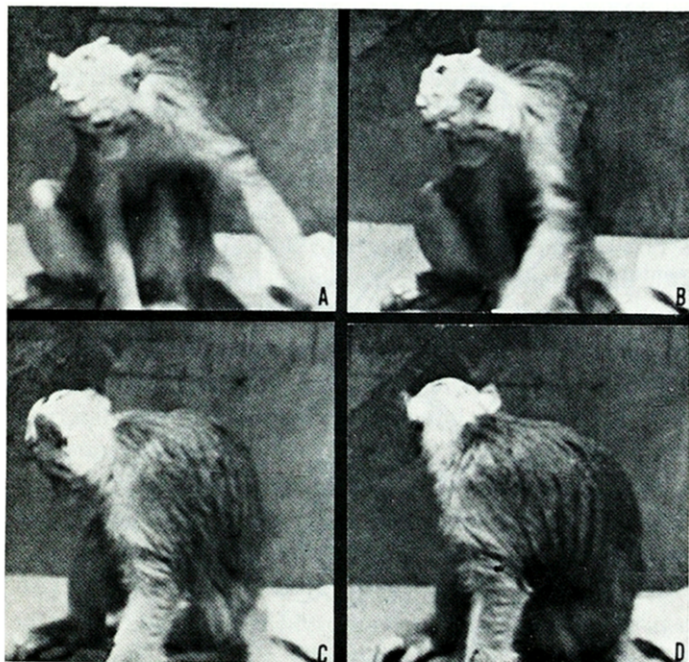


Figure 4. Photographs in an A-D sequence illustrating hemirotation of monkey 8536 from implantation of penicillin discs on the more ventral portion of this parietal region.

THE PATHWAYS TO BRAIN STEM AND SPINAL CORD

Pathways (Figure 5) involved in discharges from the cortical areas tested in this series of stimulations are well known and have been frequently described in connection with various studies. Consequently they are only summarized briefly in the present account and the literature dealing with them – which is very great in amount – is suggested through references with bibliographies which make various previous accounts available to those interested in them.

The extreme capsule (Figure 5) carries many interconnections between the

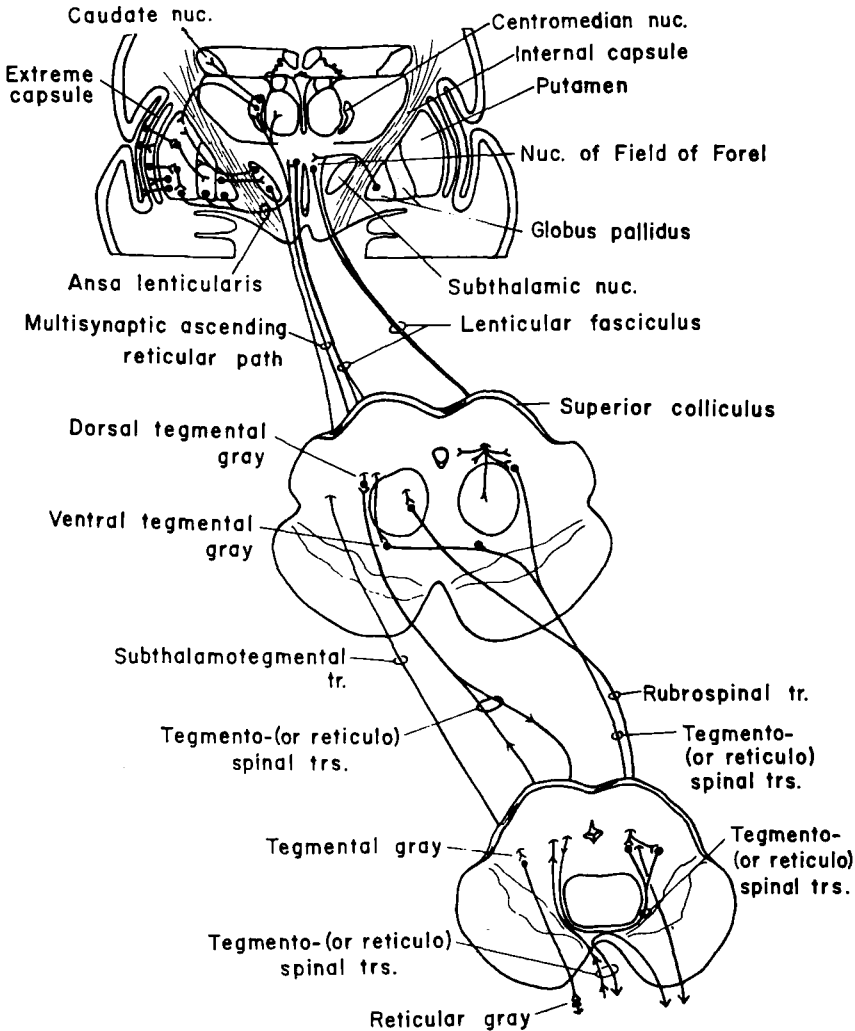


Figure 5. Diagram of the descending paths from the island cortex through the midbrain levels and of the ascending system from the dorsal tegmental gray through thalamus, putamen and claustrum to island cortex.

frontal cortex and the rostral part of the superior temporal area, with partial relay in course in the island cortex. Similar interrelations exist between the posterior part of the superior temporal gyrus with at least the posterior part of the island, and with the parietal cortex. These interrelations are so familiar to anyone who has placed lesions in any of these areas (as well as being prominent landmarks in normal material) that they do not require special documentation.

The insular regions are interconnected with the claustrum and, directly and by way of synapse in the claustrum, with the putamen (Figure 5). Such relations have been shown most satisfactorily by RAE (1954) and in our preparations. Over internuclear fibers the putamen discharges to the globus pallidus (FOIX and NICOLESCO, 1925).

From the putamen and the globus pallidus arises the well recognized and frequently documented ansa system (WILSON, 1914; PAPEZ, 1942; WOODBURNE, CROSBY and MCCOTTER, 1946; LAURSEN, 1955; NEUMANN, 1959; CROSBY, HUMPHREY and LAUER, 1962; CROSBY *et al*, 1966). This system which embryologically and phylogenetically is a fan of fibers, separates into three major divisions in man (and in varying degrees in other mammals) by the interdigitating of its fascicles with those of the internal capsule. These major subdivisions are the ansa lenticularis, the subthalamic fasciculus and the lenticular fasciculus.

The ansa lenticularis, (Figure 5), the most rostral and the most ventral of the three components of the ansa system, in its course from the basal ganglia into the thalamus, arises chiefly from the putamen, the globus pallidus and the substantia innominata (WOODBURNE *et al*, 1974) but carries corticotegmental fibers (BERKE, 1960) from various additional motor (or extrapyramidal) cortices. The bundle enters the diencephalon ventral to the internal capsule; it arches dorsomedially around the subthalamic nucleus to the nucleus of the field of Forel. In this nucleus there is a major synapse of the components of basal ganglion origin. How complete this relay is has been a matter of considerable dispute (WILSON, 1914; RANSON and RANSON, 1941, 1942; PAPEZ, 1942; WOODBURNE *et al*, 1946; LAURSEN, 1955; NEUMANN, 1959 and many others) but probably the cortical component does not terminate in this nucleus (BERKE, 1960). From the nucleus of the field of Forel fascicles join this cortical component and the bundle proceeds in the descending lenticular fasciculus to the midbrain. Its fibers may terminate in the red nucleus. Certainly they end in the tegmental gray ventral and caudal to this nucleus (WOODBURNE *et al*, 1946; LAURSEN, 1955; CROSBY *et al*, 1966).

WHITTIER and METTLER (1949a, b) and many other observers have documented the interconnections between the basal ganglia and the subthalamic nucleus by way of the subthalamic fasciculus. Such fascicles arise and/or end in the putamen and the globus pallidus. In their course between the two areas they interdigitate with the fibers of the posterior limb of the internal capsule (Figure 5). From the subthalamic nucleus a descending path – the subthalamotegmental tract (PAPEZ, 1946; WOODBURNE *et al*, 1946) – has been described in monkeys and is probably present in man. The midbrain tegmental gray relays over crossed and uncrossed

fibers to spinal cord levels where they are believed to end on dorsal funicular cells which discharge to gamma neurons.

The lenticular fasciculus of Forel (1877), the most dorsal and the most caudal component of the ansa system (Figure 5), arises from the globus pallidus chiefly but is accompanied by fibers of cortical origin (CROSBY, HUMPHREY and SHOWERS, 1959; SHOWERS, 1959; BERKE, 1960). It interdigitates with bundles in the internal capsule and then passes through the ventral thalamus in close relation to the zona incerta (to which it contributes some fibers) to reach the nucleus of the field of Forel. The cortical component in this bundle, presumably after tegmental synapse, continues caudalward to join the central tegmental bundle at midbrain levels. With and without synapse in the nucleus of the field of Forel, but augmented by fibers from this nucleus, the bundle passes back to midbrain levels to terminate in the interstitial nucleus of the medial longitudinal fasciculus (RAMÓN Y CAJAL, 1911; FOIX and NICOLESCO, 1925; MORGAN, 1927; WOODBURNE *et al*, 1946; LAURSEN, 1955), in the red nucleus (RILEY, 1943; NEUMANN, 1959; and many others) and in the tegmental gray dorsal and lateral to it (WOODBURNE *et al*, 1946; CROSBY *et al*, 1966; AUGUSTINE and CROSBY, 1975; and others). From the red nucleus a descending path, the rubrospinal tract, decussates immediately after its origin and, shifting lateralward in its course, descends through the brain stem to enter the lateral funiculus of the cord. It does not go beyond the cervical cord in monkeys (HUBER, CROSBY, WOODBURNE, GILLILAN, BROWN, and TAMTHAI, 1943) and man (NATHAN and SMITH, 1975). From the interstitial nucleus and the nucleus of Darkschewitsch, crossed and uncrossed fibers enter the medial longitudinal fasciculus to pass to motor nuclei of the brain stem (MUSKENS, 1914; and others). From tegmental gray at midbrain levels in which components of the ansa system synapse, crossed and uncrossed fascicles descend to spinal cord levels.

The fibers of the lenticular fasciculus in their termination on cells of the dorsal tegmental gray (AUGUSTINE and CROSBY, 1975) end partly on neurons contributing axons to the well known ascending multisynaptic reticular system. This path relays to the intralaminar nuclei, including the centromedian nucleus of the dorsal thalamus. JASPER and DROOGLEEVER-FORTUYN (1947) and POWELL and COWAN (1954) have demonstrated fascicles to the caudate nucleus from the more medial larger-celled part of the centromedian nucleus and fibers from its more lateral smaller-celled part to the putamen. The putamen discharges to the claustrum and directly and probably by way of the claustrum to the insular cortex. The projection of the putamen is said to be in a precise mediolateral and definite rostrocaudal pattern.

RESUME AND GENERAL CONSIDERATIONS

Rotation toward the side of the irritation resulted from implantation of a cortical irritant, penicillin, on the joint precentral and postcentral insular area of Monkey 3063 on the left and of Monkey 873 on the right. In each case the monkey

appeared dazed and the rotation was slow. Such rotation is comparable to that described in a patient with an irritating island lesion (FLEMING, personal communication).

A hemirotation toward the irritated side, in which the head, upper extremities and trunk participated, was obtained in Monkey 8536. In this monkey a penicillin-filled capsule had been placed over the portions of the area giving lower extremity movements. Placing a single large penicillin-filled disc over the opercular surface of the rostral part of the superior temporal operculum in Monkey 8536 resulted in a brief but evident counterclockwise rotation. Dr. Richard Schneider (SCHNEIDER *et al*, 1968; KAHN, CROSBY, SCHNEIDER and TAREN, 1969) had a patient who had seizures during which, unaware of his activities, he circled the teacher's desk or wastebasket at the front of the high school room. An astrocytoma was then removed which had expanded from the anterior and midtemporal region into the opercular area of the rostral part of the superior temporal region invading the frontotemporal junction and extending into the island of Reil. It followed backward toward the posterior temporal region. The tumor was removed along with approximately 6 cm of the frontal end of the temporal lobe, which included the rostral end of the temporal operculum. After a somewhat stormy postoperative period the boy recovered very well from the operation. From that time (1966) to the present he has had no seizures, is neurologically negative, has married and holds a good job.

The experiments thus far carried out by implantation of penicillin-filled discs on the cortex have not provided satisfactory evidence of rotation when these discs were placed on the parietal cortex. Thus in Monkey 8536 these attempts (separated by adequate period for recovery), following the demonstration of the extrapyramidal pattern of head and contralateral upper and lower extremity movements by electrical stimulation, were unsuccessful so far as producing rotation was concerned. In each case typical contralateral seizures were obtained but rotation did not develop. Nevertheless, in a fourth operation in which a large penicillin-filled disc was implanted on the rostral end of the temporal operculum signs of rotational movements did appear. Obviously, some of the descending paths were intact. Since there have been reports of rotational movements from stimulation of parietal cortex in several subprimate mammals (HAMEL *et al*, 1975) perhaps the regions of implantation of penicillin on the parietal cortex covered too small an area. WEIL and MARCHI preparations suggest numerous connections of the parietal cortex with the posterior part of the insula and the posterior temporal cortex.

The variations in the production of rotation from cortical irritation in primates depending upon both the relatively large size and the precise location of the irritating substance or lesion suggest the reason that such rotation is not a more commonly reported clinical finding. Yet it does occur in man and it is probable that partial rotation in patients is present more commonly than is often supposed. Perhaps such rotation has been interpreted as a torticollis or as evidence of involuntary movements from basal ganglion lesions. Moreover, the results here accumulated do not provide evidence for or against the possibility that, because

of his erect posture, an irritating lesion in lower extremity areas only of the insular precentral and postcentral gyri may produce rotation in man. The answer to this is the prerogative of the neurologist and the neurosurgeon.

Of importance in these rotational movements are the differences in the final termination of the discharge paths from the precentral agranular cortex and the postcentral granular cortex of the island region. The precentral insular cortex discharges (but indirectly) to efferent cord levels, presumably to gamma cells. The postcentral discharges, at least, are in part to tegmental areas which relay the impulses back through the dorsal thalamus, putamen and claustrum to the postcentral insular gyrus. These are interpreted by the present authors as providing for contraction of the muscles of the extremities on the side of the direction of movement (often termed the agonists) and the relaxation of the muscles (sometimes termed the antagonists) on the opposite side of the extremities.

The clinical significance of rotation as a possible sign of an irritative lesion in the island which apparently may show few other overt signs early in the progress of the case, is evident since scans may be negative and EEG recordings at present may be unsatisfactory for study of early involvements of this deeply buried cortex.

The authors of this paper wish to express their appreciation of the invitation to contribute to this volume honoring Professor Dr. J. Droogleever Fortuyn. For many years he has been a greatly valued and much admired friend of the senior author of this paper.

REFERENCES

- AUGUSTINE, J. R. and CROSBY, E. C. (1975) Extrapyrarnidal discharges from the island by way of the basal ganglia. Their significance for rotational movements. *Int. J. Neurol.* (in press).
- BERKE, J. J. (1960) The claustrum, the external capsule and the extreme capsule of *Macaca mulatta*. *J. comp. Neurol.* 115, 297.
- CALHOUN, H. D. and CROSBY, E. C. (1965) Torsional and somersaulting movements in the macaque secondary to irritative foci in or near the vestibular cortex. *Neurology (Minneapolis)* 15, 723.
- CROSBY, E. C. (1975) Anatomical and experimental basis for the effects of certain lesions in the island cortex and bordering areas. Presented at the Annual Meeting of the American Association of Neurological Surgeons, Miami, FL.
- CROSBY, E. C. and CALHOUN, H. D. (1965) A discussion of some interrelated functions of the vestibular and the ocular motor systems. In: *International Symposium on Vestibular and Oculomotor Problems*, Japan Society of Vestibular Research, University of Tokyo, Japan, 15.
- CROSBY, E. C., HUMPHREY, T. and LAUER, E. W. (1962) *Correlative anatomy of the nervous system*. New York, Macmillan Company.
- CROSBY, E. C., HUMPHREY, T. and SHOWERS, M. J. (1959) Einige Anordnungen, Verbindungen und Funktionen der supplementären motorischen Rinden. In: *Medizinische Grundlagenforschung*. Vol. 2. Ed. by K. F. Bauer. Stuttgart, Thieme, 101.
- CROSBY, E. C., SCHNEIDER, R. C., DE JONGE, B. R. and SZÖNYI, P. (1966) The alternations of tonus and movements through the interplay between the cerebral hemispheres and the cerebellum. *J. comp. Neurol.* 127, Suppl. 1, 1.

- CROSBY, E. C., TAREN, J. A. and DAVIS, R. (1970) The anterior lobe and the lingula of the cerebellum in monkeys and man. In: *Current Research in Neurosciences*. Ed. by H. T. Wycis, Basel (Switzerland), S. Karger, 22.
- FLEMING, J. F. R. (1970) personal communication.
- FOIX, C. and NICOLESCO, J. (1925) *Les noyaux gris centraux et la région mesencephalo-sous-optique*. Paris, Masson.
- FOREL, A. (1877) Untersuchungen über die Haubenregion und ihre oberen Verknüpfungen im Gehirne des Menschen und einiger Säugethiere, mit Beiträgen zu den Methoden der Gehirnuntersuchung. *Arch. Psychiat. Nervenkr.* 7, 393.
- FULTON, J. F. and CONNOR, G. (1939) The physiological basis of three major cerebellar syndromes. *Trans. Amer. neurol. Ass.* 65, 53.
- HAMEL, E. G. JR., BROWN, J. W., CAPRA, N., KINNEY, C., ROMFH, J. and AUGUSTINE, J. R. (1975) A study of certain mammalian cortical areas related to orientation in space. Presented at the 15th Annual Session, Southern Society of Anatomists, Tampa, FL.
- HUBER, G. C., CROSBY, E. C., WOODBURNE, R. T., GILLILAN, L. A., BROWN, J. O. and TAMTHAI, B. (1943) The mammalian midbrain and isthmus region. Part I. The nuclear pattern. *J. comp. Neurol.* 78, 129.
- JASPER, H. H. and DROOGLEEVER-FORTUYN, J. (1947) Experimental studies on the functional anatomy of petit mal epilepsy. *Res. Publ. Ass. nerv. ment. Dis.* 26, 272.
- KAHN, E. A., CROSBY, E. C., SCHNEIDER, R. C. and TAREN, J. A. (1969) *Correlative Neurosurgery*. Springfield, Charles C. Thomas.
- KENNARD, M. A. and ECTORS, L. (1938) Forced circling in monkeys following lesions of the frontal lobes. *J. Neurophysiol.* 1, 45.
- LAURSEN, A. M. (1955) An experimental study of pathways from the basal ganglia. *J. comp. Neurol.* 102, 1.
- MAXWELL, J. A. (1974) personal communication.
- MORGAN, L. O. (1927) The corpus striatum. A study of secondary degenerations following lesions in man and of symptoms of acute degenerations following experimental lesions in cats. *Arch. Neurol. Psychiat.* 18, 495.
- MUSKENS, L. J. J. (1914) An anatomico-physiological study of the posterior longitudinal bundle in its relation to forced movement. *Brain* 36, 352.
- NATHAN, P. W. and SMITH, M. C. (1975) Rubrospinal and central tegmental tracts in man. Presented at the Xth International Congress of Anatomy, Tokyo, Japan.
- NEUMANN, M. A. (1959) Combined degeneration of globus pallidus and dentate nucleus and their projections. *Neurology (Minneap.)* 9, 430.
- PAPEZ, J. W. (1942) A summary of fiber connections of the basal ganglia with each other and with other portions of the brain. *Res. Publ. Ass. nerv. ment. Dis.* 21, 21.
- PAPEZ, J. W. (1946) Subthalamo-tegmental tract. *Anat. Rec.* 94, 524.
- PENFIELD, W. and RASMUSSEN, T. (1950) *The cerebral cortex of man*. New York, Macmillan Company.
- POWELL, T. P. S. and COWAN, M. W. (1954) The connexions of the midline and intralaminar nuclei of the thalamus of the rat. *J. Anat. (Lond.)* 88, 307.
- RAE, A. S. L. (1954) The connections of the claustrum. *Confin. Neurol. (Basel)* 14, 211.
- RAMÓN Y CAJAL, S. (1911) *Histologie du Système Nerveux de L'Homme et des Vertébrés*. Paris, Maloine.
- RANSON, S. W. and RANSON, S. W., JR. (1941) Strionigral or nigrostriatal fibers. *Trans. Amer. neurol. Ass.* 67, 168.
- RANSON, S. W. and RANSON, S. W., JR. (1942) Efferent fibers of the corpus striatum. *Res. Publ. Ass. nerv. ment. Dis.* 21, 69.
- RILEY, H. A. (1943) *An atlas of the basal ganglia, brain stem and spinal cord*. Baltimore, Williams and Wilkins.
- SCHNEIDER, R. C., CALHOUN, H. D. and CROSBY, E. C. (1968) Vertigo and rotational movement in cortical and subcortical lesions. *J. neurol. Sci.* 6, 493.
- SCHNEIDER, R. C., CALHOUN, H. D. and KOOI, K. A. (1971) Circling and rotational automatisms in patients with frontotemporal cortical and subcortical lesions. *J. Neurosurg.* 35, 554.
- SHOWERS, M. J. C. (1959) The cingulate gyrus: additional motor area and cortical autonomic regulator. *J. comp. Neurol.* 112, 231.

- WHITTIER, J. R. and METTLER, F. A. (1949a) Studies on the subthalamus of the rhesus monkey. I. Anatomy and fiber connections of the subthalamic nucleus of Luys. *J. comp. Neurol.* 90, 281.
- WHITTIER, J. R. and METTLER, F. A. (1949b) Studies on the subthalamus of the rhesus monkey. II. Hyperkinesia and other physiologic effects of subthalamic lesions with special reference to the subthalamic nucleus of Luys. *J. comp. Neurol.* 90, 319.
- WILSON, S. A. K. (1914) An experimental research into the anatomy and physiology of the corpus striatum. *Brain* 36, 427.
- WOODBURNE, R. T., CROSBY, E. C. and MCCOTTER, R. E. (1946) The mammalian midbrain and isthmus regions. Part II. The fiber connections. A. The relations of the tegmentum of the midbrain with the basal ganglia in *Macaca mulatta*. *J. comp. Neurol.* 85, 67.

The first issue of this journal was published in September 1974, several months after the decision was made, to publish this successor of *Psychiatria, Neurologia and Neurochirurgia*. The first volume was completed about one year afterwards. The financial year, however, started in January 1974, so the volumes of the journal did not run parallel from the start.

Caused by the enthusiasm and the help of many authors nowadays, it seems to be possible to increase the number of issues in next year's volume (1977 only). We certainly hope that the enthusiasm and literary activity of the many known and yet not-known authors of clinical and clinico-scientific articles will continue to get 'Clinical Neurology and Neurosurgery' more regularly published and even more interesting.

Editor in Chief,
Prof. Dr. J. M. Minderhoud.