THE BRITISH JOURNAL OF OPHTHALMOLOGY

APRIL, 1939

COMMUNICATIONS

FOVILLE'S SYNDROME—RECORD OF A CASE

BY

J. R. MUTCH, M.D., D.O.M.S.

DEPARTMENT OF SURGERY, UNIVERSITY, ABERDEEN

It is generally held that paralysis of the 6th nerve is of uncertain value as a localizing sign in cerebral disease. This is true only if the paralysis is peripheral in type and unaccompanied by paralysis of any other cranial nerve. When, however, the lesion involves the nucleus of the 6th nerve or the higher co-ordinating centres, the features of the resulting paralysis are such as to render exact localization possible. I submit the following case as an example of a pontine lesion with certain associated focal signs, the study of which may throw some light on the function of this complex region of the brain stem.

Case report

F. D., a male, age 56 years, consulted me because of failing vision and watering of the left eye.

History.—Three years previously, he noticed one morning that the left side of his face was twisted, and that he was unable to close the left eye. He was not aware of any seizure, and did not feel ill. A few months later the left eye began to water and was occasionally sore. Shortly afterwards he became unsteady on his legs and felt as though he was falling to the left, although he very rarely fell. About the same time his speech became indistinct and at times difficult to understand.

Family History.—There was nothing of note in the family history except that his mother died of a "shock." Patient was an only child.

Past illnesses.—He had the usual illnesses of childhood, and had influenza 5-6 years ago, but otherwise had been very healthy.

Present condition.—He had no headache, sickness or vomiting. Digestion was good, he enjoyed his food and was not constipated. Lately he had suffered from slight frequency of micturition, having to rise once or twice during the night to empty his bladder. He was breathless on exertion, but did not suffer from palpitation. He had suffered no impairment of power and had not noticed anaesthesia or abnormal sensations. On his own admission he was a confirmed alcoholic.

Examination

He had a good colour and was somewhat obese.

Nervous system.—Sense of smell was perfect. There was no sensory loss on the face or on the corneae. There was present complete paralysis and wasting of all the muscles of expression on the left side of the face. Hearing was slightly diminished on both sides. The tongue protruded quickly, straight and showed some coarse tremors. Sense of taste was diminished equally over the entire surface of the tongue, no difference being found between the two sides or between the anterior and posterior portions. Patient would not admit however that he had defective sense of taste.* Speech was hoarse and slurring and sibilants caused some difficulty. The palatal reflexes were present. There was no loss of power in the limbs; no areas of anaesthesia, or loss of bone, joint or muscle sense. The biceps, triceps and supinator jerks were present and equal; the ankle jerks were absent; the right knee jerk was present, but the left was absent. When he was asked to walk clock-wise around a chair he tended to go off to the left. He showed compass point walking. When he was placed with his feet close together with eyes closed, he tended to fall backwards and to the left. There was no past pointing or intention tremor. Dysidiadochokinesis and hypotonia were absent.

Cardio-vascular system.—The heart was not enlarged. The systolic blood-pressure was 148 mm. Hg and the diastolic 88 mm. No adventitious sounds were heard in the chest. The Wassermann reaction of the blood and the C.S.F. was negative. No abnormal constituents were found in the urine. A radiogram of the skull did not demonstrate any abnormality.

*I am of the opinion that the defective sense of taste was due to a local anaesthesia of the papillae from excessive doses of alcohol.

Ophthalmological examination.—There was ptosis of the right upper lid and lagophthalmos of the left lower lid. The right eye closed tightly but the left remained open. On an attempt being made at closure, the eyeball turned upwards so that only the sclera showed in the palpebral fissure. There was frequent blinking of the lids of the right eye. The left pupil was larger than the right; both reacted normally to light and to near vision. There was a left internal strabismus of 10 degrees. The right eye moved fully to the right but the movement of the left eye to the right was slightly limited. This movement to the right was accompanied by gross horizontal nystagmus of the right eye, with nystagmus of a much finer excursion in the left eye. There was complete loss of conjugate movement to the left. Upward and downward movements were full. Convergence was full and well maintained. Right vision was 6/18, and with + 0.5 sph. it was 6/12. With the addition of + 2.5 sph. Jaeger 2 was read. Left vision was 6/12, and with + 2.5 sph. Jaeger 1 was read. Tension was normal in both eyes. As the patient complained of troublesome watering of the left eye, lacrimal secretion was certainly not diminished.

Ophthalmoscopic examination.—There were peripheral lens striae in both eyes. The optic discs were rather pale, and the retinal vessels sclerosed.

Visual fields.—The visual fields showed slight concentric contraction for a 5 mm. white disc. There was no central scotoma for colour.

Summary of positive findings

1. Paralysis and wasting of all the muscles of the left side of the face.
2. Left internal strabismus.
3. Loss of conjugate movement of both eyes to the left.
4. Right ptosis.
5. Unequal pupils.
6. Horizontal nystagmus when looking to the right.
7. Slurring speech.
8. Sclerosis of retinal vessels.
9. Unsteadiness of gait with a tendency to fall to the left.

Discussion on positive findings

The facial paralysis.—Since the upper as well as the lower facial muscles on the left side were paralysed and wasted, the lesion must be a lower motor neuron lesion, and may be anywhere between the stylo-mastoid foramen and the facial nucleus in the

pons. Evidence, however, will be given that the 7th nerve was involved where its fibres sweep round the 6th nerve nucleus.

The normal action of the external rectus muscle.—The action of one individual external rectus muscle is to rotate the eyeball externally along its horizontal axis. In no movement of the eyes however is one external rectus muscle individually put into action; it is always associated with some other muscle of the other eye to produce a co-ordinated movement of the two eyes. In lateral movement of the eyes the action of the homo-lateral external rectus muscle is associated with the contra-lateral internal rectus muscle.*

Convergence and divergence.—When the eyes are at rest the visual axes of the two eyes are parallel, or more usually slightly divergent. Before a near object can be fused to form a single image, the visual axes must converge, the amount of convergence depending upon the distance of the object from the eyes, and to a lesser extent upon the pupillary distance. It is now generally accepted that there is a centre for convergence, and that it is situated in the median nucleus of Perlia. When the eyes are in a state of convergence, before the visual axes can again become parallel the eyes must diverge. This can only be brought about by the action of the external recti. There is some divergence of opinion as to the existence of a centre for divergence (Duke-Elder, 1932); those dissenting maintain that the visual axes will attain a parallel position upon relaxation of the internal recti. With this hypothesis I do not agree, since according to the universally accepted theory of reciprocal innervation, upon relaxation of convergence the external recti must be brought into action. Furthermore when conjugate lateral movement and convergence take place as a combined action, before the eyes can again diverge, the eyes meantime remaining in the lateral position, the intervention of a divergence centre would appear to be essential.

Centre for lateral conjugate movement.—There has long been experimental and clinical proof that a centre for lateral movement of the eyes is situated in the second frontal gyrus in the posterior part of the frontal convolution (Russell, 1894). Vascular lesions in this area tend to stimulate the centre, causing the eyes to deviate away from the side of the lesion; this stimulation later gives place to paralysis, which causes loss of lateral movement towards the side opposite to that of the lesion.

Nerve path from cortex to supra-nuclear centre.—The exact route of this pathway has not as yet been accurately traced. Clinical proof, however, has been given by (Holmes, 1921) and

* In this connection it is worthy of note that I have been unable to find in the literature a description of a case that demonstrated a supra-nuclear 6th nerve lesion which caused an isolated paralysis of one external rectus muscle.

(Collier, 1927) that it decussates before reaching the supra-nuclear centre. (Riley, 1930) gives a description of the route, but omits the decussation. His description is as follows: "fibres arising in the cells of Betz pass into the corona radiata and enter the genu of the internal capsule. They then run downwards along with other cortico-bulbar axons which together constitute the aberrant pyramidal tract. The peduncular contingent of the pyramidal tract that is destined for the supply of lateral movement leaves the cortico-nuclear tract as two bundles of fibres, the pes lemniscus superficialis and the pes lemniscus profundus in the mid brain and upper pontine regions, descend for a short distance in the mesial fillet and then proceed dorsally in the tegmentum to the centre for lateral movement which is situated close to the abducent nucleus."

Experimental stimulation of the visual cortex.—If the visual area of the occipital cortex be stimulated with faradic current conjugate deviation of the eyes takes place, the direction of the movement depending upon the area stimulated (Schäfer, 1888).

Reflex of regard.—When an image of an external object is projected on to the periphery of the retina, this reflex so turns the eyes that the image is projected on to the maculae of both eyes. A moving image on the periphery of the retina appears to stimulate the reflex better than a stationary image, so the reflex is really for the preservation of the organism. Moving objects approaching from the side stimulate the periphery of the retina, the impulse is carried to the occipital lobes and passes to the supranuclear centre for lateral movements of the eyes. The eyes are immediately turned so that the image of the approaching object is projected on to the macula, there to be clearly defined as a source of danger or otherwise and avoided or welcomed as the case may be.

The fixation reflex.—When the image reaches the macula, this reflex tends to keep it there, the eyes moving to keep pace with the object in all its excursions.*

Supranuclear centres.—As no single oculo-motor muscle can individually be brought into action, supranuclear centres would appear to be necessary to correlate the action of groups of muscles so as to produce a combined and co-ordinated movement of the two eyes. The co-ordinated movements for which supranuclear centres appear to be necessary are:—

1. Convergence.
2. Divergence.
3. Conjugate lateral movement to the right.

* This reflex not only turns the eyes but also the head. Anyone suffering from a stiff neck is not long left in doubt about the neck muscles being accessory eye muscles.

4. Conjugate lateral movement to the left.
5. Upward movement.
6. Downward movement.

Lesions causing loss of convergence, and paralysis of conjugate lateral, upward, or downward movement as isolated defects are comparatively common. Loss of divergence or more exactly loss of relaxation of convergence is not so common. A case was reported by (Dumphy, 1928), however, in which diplopia was experienced when a distant object was looked at. There was no strabismus, eye movements were full and the diplopia disappeared when a near object was looked at. A patient of my own had the same complaint, but the defect was spasm of convergence and accommodation—a hysterical manifestation cured by luminal, and atropine by mouth, as she would not allow drops to be put into her eyes. The hypothesis that the 6th nucleus was the pacemaker for lateral conjugate movement of the eyes, and that the centre was actually situated in the 6th nerve nucleus held sway for many years (Kidd, 1922). Accumulated experimental, pathological and clinical evidence makes this hypothesis untenable and it is now generally believed that a supra-nuclear centre exists close to but distinct from the 6th nerve nucleus. The accumulated evidence that there is a supra-nuclear centre and that the connecting fibres run in the posterior longitudinal fasciculus is as follows.

1. In no experimental or pathological lesion of a 3rd nerve has chromatolysis been found in the opposite 6th nucleus. This proves that fibres from the 6th nucleus do not enter the contralateral 3rd nerve (Kidd, 1922).

2. Injuries of the internal capsule or peduncle do not cause degeneration of fibres in the posterior longitudinal fasciculus; there must therefore be a relay station before the fibres reach the posterior longitudinal fasciculus (Spiegel, 1933).

3. In all cases of paralysis of conjugate movement examined histologically, degeneration of the fibres of the posterior longitudinal fasciculus has been found (Kidd, 1922).

4. Certain instances of loss of movement of the homolateral eye outwards with retention of the conjugate movement of the contralateral eye inwards have been described in which the 6th nucleus was completely destroyed, thus showing that the centre for lateral conjugate movement cannot be situated in the nucleus itself, although other pathological evidence would indicate that the centre was situated close to the nucleus (Riley, 1930).

Many experiments have been performed on animals in an endeavour to place the centre accurately. Different areas of the pons have been stimulated and erroneous conclusions have been drawn from the resulting eye movements. Duval and Laborde

(1880) thought they obtained conjugate movement of the eyes by stimulating the 6th nucleus but the movement was probably brought about by stimulating the adjacent posterior longitudinal fasciculus or vestibulo-ocular pathway. (Spiegel, 1933) stimulated the posterior longitudinal fasciculus and obtained conjugate lateral movement. As he stated that cortical fibres descend in the posterior longitudinal fasciculus he had no reason for his assumption that he was stimulating fibres that proceeded to the homolateral 6th and contralateral 3rd nuclei.

If we assume that there is a supra-nuclear centre for lateral conjugate movement, and that the connecting fibres run in the posterior longitudinal fasciculus, then we should be able to differentiate clinically between lesions situated in the following situations.

1. Infranuclear.
2. Nuclear.
3. Internuclear.
4. Supranuclear. $\left\{ \begin{array}{l} \text{cortical.} \\ \text{occipital.} \\ \text{vestibular.} \end{array} \right.$

(1) *Infranuclear*.—A lesion of the 6th nerve peripheral to the nucleus causes a paralysis of the external rectus muscle of the same side. The lesion is of the lower motor neuron causing a flaccid paralysis of the muscle supplied. The eye deviates inwards about 10° ; there is complete loss of outward movement on the side of the paralysis with full movement inwards of the opposite eye.

(2) *Nuclear*.—A lesion of the 6th nerve nucleus also causes a lower motor neurone lesion indistinguishable from a lesion of the peripheral nerve. As an isolated sign, it would be clinically impossible of diagnosis. Fortunately a lesion limited to complete destruction of the cells of one 6th nerve nucleus is extremely rare (Siemerling and Boedeker, 1897) and can be due only to a primary degeneration of the nerve cells. If due to a vascular lesion or tumour, surrounding structures are involved which give rise to a combination of signs which localize the lesion with extreme accuracy. Such a combination of signs in this instance is known as Foville's syndrome, which consists of paralysis of conjugate lateral movement towards the side of the lesion associated with a peripheral paralysis of the 7th nerve on the same side. Besides destruction of the 6th nucleus there is possibly destruction of the supra-nuclear centre or destruction of the posterior longitudinal fasciculus. Haemorrhage would cause a much more widespread lesion than would be caused by thrombosis or embolism blocking a single median branch of the basilar artery; the former condition would therefore involve other tracts which would give additional signs.

(3) *Internuclear*.—An inter-nuclear lesion would be situated in the posterior longitudinal fasciculus and would give rise to the following signs.

(a) Paralysis of inward movement of the contralateral eye upon lateral conjugate movement, with retention of full inward movement on convergence and with full outward movement of the homolateral eye (Holmes, 1921).

(b) Nystagmus.

(4) *Supranuclear*.—If the lesion involves the centre, then all reflex and voluntary lateral movement towards the side of the lesion is abolished. If above the supra-nuclear centre there are three possibilities.

FIG. 1.

Front view of F. D. showing flaccid paralysis of all the muscles of expression of the left side of the face.

FIG. 2 (a).

The eyes in ordinary light. There is right ptosis and a left lagophthalmos; the left pupil is larger than the right; there is a left internal strabismus of 10 degrees.

FIG. 2 (b).

The eyes in darkness, photograph taken by flash-light. The pupils are half dilated, the left still being the larger.

Fig. 2 (c).

Attempt made to turn the eyes to the right. There is a full movement of the right eye to the right, but the movement of the left eye to the right is slightly limited.

FIG. 2 (d).

Attempt made to turn the eyes to the left. If the corneal reflections are compared with 2 (a) it will be seen that there is complete loss of movement of both eyes to the left.

FIG. 2 (e).

Upward movement of both eyes is full.

(a) *Cortical*.—A lesion of the frontal lobe causing destruction of the centre for voluntary lateral movement or a lesion in the descending tract to the mid brain, would cause loss of voluntary movement away from the side of the lesion if the lesion is above the decussation of the fibres, and towards the side of the lesion if below the decussation. There is no diplopia as reflex control from the occipital lobes, cerebellum and vestibular system is retained. The normal tonus supplied by the 6th nucleus to the external rectus muscle is also retained.

(b) *Occipital*.—With a lesion of the pathway from the superior colliculus to the supra-nuclear centre a patient would be unable to follow an object with the eyes when it is moved laterally away from the side of the lesion.

If a patient has a lesion involving an occipital lobe that is producing a hemianopia, the reflex of regard must of necessity be abolished as all objects to the hemianopic side are not seen. As the fixation reflex in my opinion is entirely macular in origin a lesion of one occipital lobe should not interfere with it.

(c) *Vestibular*.—A lesion of the vestibular nucleus or vestibulo-ocular tract would give rise to nystagmus and loss of the head turning reflex, accompanied by unsteadiness of gait with a tendency to fall to the side of the lesion (Oppenheim, 1911).

To make a complete examination of conjugate lateral movements of the eyes the following three tests are necessary:—

1. The patient is asked to look to the right and to the left, the head meantime being kept stationary.
2. The eyes are made to follow the excursions of an object moved laterally, first to one side and then to the other.
3. The patient is asked to fix an object in front of the eyes, the head being meantime turned passively to the right and to the left.

Description of the pons at the level of the 6th nerve nucleus.—The relative anatomy can most easily be described by means of a cross section of the pons at the level of the 6th nerve nucleus (Fig. 3).

It will be seen that the 6th nucleus lies in the floor of the 4th ventricle near the mid line and beneath the colliculus facialis.

The fibres from the nucleus pass forwards and downwards without decussating through the whole thickness of the pons, passing medial to the superior olivary nucleus and lateral to the pyramidal tract, and emerge as several rootlets in the groove between the pons and the medulla, lateral to the prominence of the pyramid.

FIG. 3.

From Gray's text-book of Anatomy, 26th Edition. (With kind permission of the publishers.)

FIG. 4.

Showing the probable situation of the lesion.

The 7th nerve nucleus.—The nucleus of the 7th nerve is situated in the ventral portion of the tegmentum medial to the descending root of the 5th nerve and lateral to the superior olive. The fibres of the 7th nerve leave the nucleus and run towards the floor of the 4th ventricle, encircling the 6th nerve nucleus like a horse-shoe. They then traverse the tegmentum and transverse fibres of the pons and emerge between the 8th and 6th nerves. The nucleus receives fibres from the pyramidal tract of the opposite side. In addition some of the efferent fibres of the facial nerve take origin from the superior salivary nucleus which lies in the reticular formation dorsilateral to the caudal end of the motor nucleus. This sends its fibres to join the motor root by which they are ultimately distributed through the chorda tympani to the submandibular and sublingual salivary glands (Gray, 1935). Close to the mid line and lying near the floor of the 4th ventricle and in close relation with the root fibres of the 7th nerve and the 6th nucleus there are two bundles of fibres, the posterior longitudinal fasciculus and the tecto-spinal tract.

The posterior longitudinal fasciculus.—This tract is made up of ascending and descending fibres. The ascending fibres come from the following sources (a) Deiter's nucleus by means of which connection is established with the 6th and 3rd nerves, bringing them under the direct influence of the cerebellum and vestibular systems.

(b) Fibres from the sensory nucleus of the 5th nerve correlating the movements of the eyes with sensory impressions received from the head, especially from the conjunctivae.

(c) Fibres from cells in the ventral gray column of the spinal cord.

(d) Fibres from the 6th and 4th cranial nerve nuclei. The descending fibres are largely derived from the nucleus interstitialis of Cajal.

The tecto-spinal tract.—This tract rises in the superior colliculi and passes by way of the arciform fibres to the dorsal tegmental decussation of Meynert. From this point it forms a compact bundle which descends in relation with the posterior longitudinal fasciculus through the pons and medulla into the ventral white column of the spinal cord. It serves to activate reflex movements in the facial musculature, in the arms, trunk and neck in response to visual impressions.

Blood supply to the pons

For long the minute anatomy of the blood supply to the pons was not known. Stopford in 1915, however, made an exhaustive investigation, and it is from his report that the following description is mainly extracted.

Normally the pons receives its blood supply from the basilar artery and its branches. The basilar artery originates at the lower border of the pons by the fusion of the two vertebral arteries and terminates at the upper border of the pons by dividing into the two posterior cerebral arteries. It lies on the ventral aspect of the pons in the median groove formed by the pyramidal fibres. It is separated from the basisphenoid by the arachnoid and dura mater only.

Pontine branches.—A. Minute branches which arise from the surface of the basilar artery lying in contact with the pons which at once enter the substance of the brain along the median groove.

B. A set of transverse rami which extend laterally and subdivide as they proceed into smaller branches which penetrate the ventral surface of the pons at right angles to the parent vessel. These vessels are generally arranged symmetrically on the two sides, but are variable in size and number.

The anterior inferior cerebellar artery.—This artery passes laterally and somewhat caudally from its origin over the ventral surface of the pons towards the cerebellar hemisphere of its own side, on to the anterior part of the inferior surface of which it extends to anastomose with the posterior inferior cerebellar artery.

The median pontine branches are all end arteries but (Stopford, 1915) thought that the terminal ramifications spread out and ran cephalwards for a short distance in the grey matter in the floor of the 4th ventricle. The median pontine branches supply the structures immediately lateral to the middle line in the tegmental part. This includes the nuclei of the 6th, 4th and 3rd nerves, the fibres of the 7th nerve; the median longitudinal bundle, the medial lemniscus, and the tecto-spinal and thalamo-olivary tract; transverse pontine fibres and the medial part of the corpus trapezoidum. The transverse fibres supply the brachium pontis, lateral part of the corpus trapezoidum, superior olive and the nuclei of the 5th, 7th and 8th nerves. According to (Stopford, 1915) the basilar was found to follow a more constant course than any of the cerebral arteries he studied, but it manifested arterial disease much more frequently than the others. He points out that embolism of the basilar artery is rare because fragments which have passed uninterruptedly through the vertebral would scarcely be likely to become lodged in the former artery which is larger than the latter. If obstruction occurs it is seen only at the bifurcation to form the two posterior cerebral arteries. Occlusion from embolism or thrombosis inevitably results in death as degeneration ensues of all the descending fibres of both sides including those which pass to the vital centres of the bulb and caudal part of the pons. In conducting this investigation on the cadaver

Stopford ligatured the basilar artery just before it divided into its terminal branches and also the lateral branches. He then injected a dye into the caudal end of the artery. Sections of the pons were then made, the stained area representing the distribution of the median branches. No attempt was made to inject individual median branches so it is not known whether or not the 6th nerve nucleus is supplied by a separate and distinct branch. Bernheimer (1899), however, traced a separate artery to the Edinger-Westphal nucleus, so possibly the 6th nucleus and its vicinity is supplied by a separate artery.

Diagnosis

From the evidence supplied and taking into account the sudden onset, the non-progressive nature of the lesion, the state of the retinal arteries and the fact that the lesion is confined to such a small area of the pons my diagnosis is thrombosis of a median branch of the basilar artery.

BIBLIOGRAPHY

- ANTONI.—Eine eigenartige symmetrische Motilitätsstörung der Augen (Syndrom der internukleären Unterbrechung des hinteren Langsbündels). *Jahrb. f. Psychiat. u. Neurol.*, Vol. XLV, pp. 15-19, 1926.
- COLLIER.—Nuclear ophthalmoplegia, with special reference to retraction of the lids and ptosis and to the lesions of the posterior commissure. *Brain*, Vol. L, p. 488, 1927.
- Savill memorial oration on localization of function in nervous system. *Brit. Med. J.*, Vol. I, pp. 55-61, January 11, 1930.
- DUKE-ELDER.—Text-book of Ophthalmology, Vol. I, 1932.
- DUMPHY.—Paralysis of divergence. *Amer. J. Ophthalm.*, Vol. II, pp. 298-299, April, 1928.
- DUVAL and LABORDE.—*Jl. de L'anat. et de la Physiol.*, Vol. XVI, p. 56, 1880.
- DUANE.—The associated movements of the eyes, their nerve centres, conducting paths, production, varieties, and rearrangements. *Amer. J. Ophthalm.*, Chicago, 3 s., Vol. VII, pp. 16-26, 1924.
- GRAY.—Text-book of Anatomy. 26th Edition.
- HOLMES.—Palsies of the conjugate ocular movements. *Brit. J. Ophthalm.*, London, Vol. VI, pp. 241-350, 1921.
- Observations on ocular palsies. *Brit. Med. J.*, Vol. II, pp. 1165-1167, December 26, 1931.
- KIDD.—The fourth cranial nerve. *Brit. J. Ophthalm.*, London, Vol. VI, pp. 49-64, 1922.
- Vertical eye-movement testing in the positions of abduction and adduction. *Rev. Neurol. and Psychiatry*, Vol. II, p. 799, 1904.
- Direct trochlear and crossed oculomotor fibres. *Rev. Neurol. and Psychiatry*, Vol. XI, p. 507, 1913.
- OPPENHEIM.—Text-book of Nervous Diseases. Edinburgh, 1911.
- RUSSELL.—An experimental investigation of eye movements. *Jl. Physiol.*, Cambridge, Vol. XVII, pp. 1-26, 1894.
- Further researches on eye movements. *Jl. Physiol.*, Cambridge, Vol. XVII, pp. 378-389, 1894.
- RILEY.—Central nervous system control of ocular movements and disturbances of this mechanism. *Arch. of Ophthalm.*, Vol. IV, p. 640, November; p. 885, December, 1930.
- SPIEGEL.—Rôle of vestibular nuclei in cortical innervation of eye muscles. *Arch. Neurol. and Psychiatry*, Vol. XXIX, pp. 1084-1097, May, 1933.
- SIEMERLING and BOEDEKER.—Chronische fortschreitende Augenmuskellähmung und progressive Paralyse. *Arch. f. Psychiatry*, Berlin, Vol. XXIX, p. 420; p. 716, 21 pl., 1896-7.
- SCHÄFER.—A Comparison of the Latency Periods of the Ocular Muscles on Excitation of the Frontal and Occipito-Temporal Regions of the Brain. *Proc. Roy. Soc.*, Vol. XLIII, p. 411, 1888.
- STOPFORD.—The arteries of the pons and medulla oblongata. *Jl. of Anat. and Physiol.*, Vol. L, p. 131, 1915-6.