THE CROONIAN LECTURES ON CEREBRAL LOCALISATION.

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LECTURE III.

SCHÄFER'S further investigations, in conjunction with Sanger-Brown, led him to agree with Munk that complete unilateral extirpation of the occipital lobe alone caused persistent hemiopia, while bilateral extirpation caused total and enduring blindness. Admitting, however, that the lesions described by them were the cause of hemiopia or total blindness, it does not follow that these results are due to removal of the occipital lobe as such. Schäfer himself¹ admits that the visual area embraces not only the occipital lobe, but, perhaps also part, or the whole, of the angular gyrus. The relations of the different portions of the visual centres to the retinae, founded on the phenomena of electrical irritation, as well as other facts, necessitate that the angular gyrus (its posterior limb at least, according to Schäfer) should be included in the visual area; more, therefore, than the occipital lobe proper. If total blindness, therefore, is caused by removal of the occipital lobes in the line of the parieto-occipital fissure, it is necessary to suppose that by this operation the medullary connections of the whole of the visual area become implicated. Schäfer² has himself suggested that fibres connected with the cortex of the adjoining parts of the brain, and especially of the angular gyrus, may be cut off along with the occipital lobe, and that this is the real explanation is supported by many considerations.³

Lesions of the occipito-temporal region alone are competent to produce hemiopia or complete blindness, according as the lesion is unilateral or bilateral, altogether apart from affection of the angular gyrus, or any other portion of the occipital lobe. I have myself recorded instances⁴ in which lesions of the occipito-temporal region were followed by temporary hemiopia, and probably similar facts have led Luciani to extend the visual area into the temporal lobe. But, not only may temporary hemiopia occur, but the hemiopia so produced may be persistent.

Here is an illustration⁵ of the brain in one of Brown and Schäfer's experiments. The operation consisted in removal of the right temporal lobe. Posteriorly, the lesion extended partly over the under surface of the occipital lobe. With the exception of this lesion of the occipital lobe, all the rest of the visual sphere was intact, yet this animal was completely hemiopic. The inference is that the lesion severed the whole of the optic radiations, for, otherwise, it should, on Schäfer's hypothesis, have caused blindness only of the lower portions of the retinae.

It appears, therefore, that the incision for the removal of the occipital lobe carried along the line of the external parieto-occipital fissure is calculated to sever the whole of the optic radiations of the occipito-angular region, which emerge from the primary optic nuclei about this level. (See Fig. 12). In support of this I quote the following experiment: I exposed the lower extremity of the left external parieto-occipital fissure, and, inserting a director at this spot between the lower surface of the occipital lobe and the tentorium, passed a stylet bent at an oblique angle along the groove in such a manner as to make a transverse incision a few millimetres in depth across the occipito-temporal region. The result of this was right hemiopia, which, however, speedily passed off, so that it was no longer clearly perceptible on the third day. A fortnight afterwards the right occipito-temporal region was similarly operated upon, the in-

cision this time being made just anterior to the lower extremity of the parieto-occipital fissure. The animal died a month after the first operation. During the whole time it survived it remained absolutely hemiopic towards the left in every part of the

Fig. 12.—Horizontal section of left hemisphere of monkey—on a level with the anterior commissure (nat. size); a.c., anterior commissure; c.A., cornu Ammonis; cl., claustrum; c.g., corpora quadrigemina; e.c., external capsule; i.c., internal capsule; i.h., island of Reil; f., anterior or descending (Meynert) pillar of fornix; f.v., ascending fibres or Viciq d'Azyr's bundle; f.M., Meynert's fasciculus; f.S., fissure of Sylvius; n.c., nucleus caudatus; n.l., nucleus lenticularis; o.r., optic radiations (Gratiolet); P., pulvinar; p., posterior commissure.

visual field. It was found after death (see Fig. 13) that the incision on the left side was shallow and not continuous, being interrupted in the region of the lingual lobule. On the right side the incision extended across the whole occipito-temporal region, and penetrated several millimetres into the substance of the brain, dividing the medullary fibres emerging from the region of the primary optic centres.

Fig. 13.

Brown and Thompson⁶ believe that removal of the occipital lobe on one side causes hemiopia to the opposite side, altogether apart from lesion of the angular gyrus, which they entirely exclude from the visual sphere. They give particulars of a monkey, in which, after removal of the left occipital lobe, right hemiopia resulted, together with right hemianæsthesia, which was still observable on the twenty-sixth day after the operation. One hundred days after the first operation the right occipital lobe was similarly removed. This was followed by complete blindness, but they state that after three weeks the animal recovered vision to some extent towards the left. They assume—but furnish no evidence of the fact—that probably a few occipital fibres had escaped injury during the second operation. The animal died of phthisis

¹ Electrical Excitation of the Visual Area, *Brain*, April, 1888.

² *Brain*, vol. x, p. 372.

³ This, however, does not fit conveniently into Schäfer's scheme, which is as follows:—1. The whole of the visual area of one hemisphere is connected with the corresponding lateral half of both retinae. 2. The upper zone of the visual area of one hemisphere is connected with the upper half of both retinae. 3. The lower zone of the visual area is connected with the lower part of the corresponding lateral half of both retinae. 4. The intermediate zone of the visual area is connected with the middle part of the corresponding lateral half of both retinae (*loc. cit.*, p. 5). The reactions would, however, be fully explained on the assumption that the angular gyrus has relations with the whole of the opposite eye.

⁴ *Phil. Trans.*, vol. ii, 1884, Experiments XXVII and XXVIII.

⁵ Figs. 4a, 4b, *Phil. Trans.*, 1883, B. 30, plate 49.

⁶ *Op. cit.*

on the 231st day. On examination it was found that the entire occipital lobe behind the angular gyrus upon each side had been removed, leaving a clean-cut surface. For some distance around this surface the pia mater was firmly adherent to the convolutions beneath, but it was stated not to have been thickened. It is certain, however, that their first lesion must have extended beyond the occipital lobe, owing to the hemianæsthesia, which does not occur when the lesions are restricted to the occipital lobe itself; and that the removal of the occipital lobes, as such, which they appear to have found equally complete on both sides, did not cause total loss of vision, is shown by the fact, which they themselves record, that the animal was still able to see, even if imperfectly, towards one side. In a second experiment they found that destruction of the left angular gyrus caused no result beyond hemianæsthesia on the right side, together with some paralysis of the right arm (!). On the ninetyeth day a second operation was performed, consisting in excision of the whole of the right occipital lobe. This was followed by left hemiopia, which still persisted when the paper was written, seventeen months after the operation. These are the only experiments on monkeys which these authors have recorded. Lannegrace,⁷ on the other hand, who has performed numerous experiments on the occipital lobes and angular gyri of monkeys, states, in accordance with my own and Yeo's results, that destruction of the occipital lobe causes no appreciable impairment of vision, whereas destruction of the angular gyrus produces crossed amblyopia of a temporary character. He reports two cases of successive lesion of the angular gyri. In the one the first lesion induced crossed amblyopia, which lasted four days. The second lesion, however, produced no appreciable alteration. In the other the first lesion again caused crossed amblyopia, which disappeared in two days, while the second gave rise to lasting amblyopia. These results, which are similar to those obtained by Yeo and myself, depend, no doubt, on the degree of completeness of extirpation of the gyri.

I have already mentioned that my earlier experiments, as well as those made by Professor Yeo, show that unilateral destructive lesion of this gyrus caused temporary blindness of the opposite eye, and that bilateral destruction caused for the time complete blindness in both eyes. Though these results have been much questioned, I must insist on their accuracy. I have corroborated the occurrence of apparently complete blindness of the opposite eye, on destruction of the left angular gyrus in an animal which I lately made the subject of experiment. In this animal I had previously enucleated the left eye, so as to exclude all complications from this side. After removal of the left angular gyrus, however, the animal, though otherwise well and in complete possession of all its senses and motor powers, was evidently absolutely blind. It responded to no test of vision; would not budge from the spot, but when urged to move sprawled blindly and helplessly. This condition lasted for several hours, during which it was under observation. Next day there were indications of vision, but the animal had become so prostrated, the weather being intensely cold, that it died before any further exact observations were possible. That lesions of the angular gyrus may cause implication of the optic radiations is possible, but this result is neither necessary, nor would it account for complete loss of vision in the opposite eye. The bilateral relations of the angular gyrus account for the transient nature of the amblyopia which results from unilateral extirpation, and, as in few of my experiments was the destruction of this gyrus complete on one side or the other, it occasionally happened that removal of the other gyrus some time subsequently did not seem to impair vision either on one side or the other. When, however, the angular gyri are completely destroyed on both sides, the animal, though for the first three or four days absolutely blind, does not remain so permanently, but it never regains normal vision. This also has been confirmed by the researches of Lannegrace. Apart from the affection of vision, destruction of the angular gyrus causes no other symptoms, either motor or sensory; there is no ptosis or paralysis of the ocular muscles, and the sensibility of the conjunctiva is absolutely unimpaired.

These results, confirmed by the researches of Horsley and Schäfer, contradict the statement of Munk that the angular gyrus is the sensory sphere of the eyeball; and it will be found, on examination of Munk's own data, that the phenomena on which he relies as indicating loss of the sensibility of the eye are in reality due to loss of vision. Thus he says that after destruction of the left angular gyrus approximation of the finger to the left eye in-

variably caused winking, whereas the same threat against the right eye caused only winking when the eyelids were actually touched. This appears to be a proof of the sensibility of the eye, and the non-perception of threatened danger at a distance. The absence of winking at threatened danger he admits to be characteristic also of blindness, but he argues that, inasmuch as the animal could not be blind, presumably because the occipital lobe was intact, therefore, the non-occurrence of winking could only be due to the inability of the cortex to act on the sphincter palpebrarum! Again, he says, that when the angular gyrus has been destroyed on one side, and the eye on that side closed, the animal often fails to seize things offered it, or thrown down before it, especially when the objects are small. This I consider a clear indication of amblyopia. And he also states that after bilateral extirpation of the angular gyrus of monkeys, "after incomplete restitution"—a phrase, however, which is not very intelligible—are unable like normal monkeys to take things offered them delicately with the fingers, but make grabs at them with the whole hand. This is only a further illustration of the same imperfection of vision which I have described—namely, want of precision in prehension, and a continual tendency to place the hand over or short of the object aimed at, instead of on it at once.

Schäfer also⁸ records the symptoms in a monkey in which he destroyed both angular gyri. For the first few days the animal appeared totally blind, but vision gradually returned, and before long was quite good for distant objects. The animal could apparently see small objects, such as a raisin, at a distance, but on running up to it seemed to have some difficulty in finding it. Schäfer is of opinion that this latter fact is due to absence of vision in the antero-superior and lateral portions of the retina. I have lately carefully investigated the condition of vision in a monkey in which I had completely destroyed both angular gyri. There was no ptosis, the ocular movements were normal, the conjunctival reflexes unimpaired, sensibility was intact everywhere, and the motor powers were perfect, but, for four days at least, the animal was evidently absolutely blind. When urged to move it ran against every obstacle in its path, paid no attention to threats, could not find its food, except by groping, and appeared insensible to light flashed in its eyes. On the fifth day there were evidences of returning vision. It did not now knock its head against obstacles; would not walk over the edge of the table; showed signs of perception of light flashed in its eyes, and occasionally seemed to wince when threatened. Vision gradually improved, but continued very imperfect, especially for minute objects, which it rarely, if ever, seized quite precisely; groping at them with the whole hand, and reaching short, or over, or to the side. It appeared to see objects held above, below, and to either side much better than those held in front of its eyes. Six weeks after the operation my colleague, Professor McHardy, examined the animal, which was very docile, with me, testing every portion of the visual field by pieces of apple suspended by a delicate thread. It was concluded that vision was better in every part of the periphery than in the centre. Objects held directly before the eyes and at a little distance were apparently not clearly seen, and never laid hold of with precision. The condition remained unchanged for three months after the operation, similar tests being from time to time applied, and with the same result. I noted also that the animal, when examining any object, always held it at full arm's length from its eyes. The phenomena observable in this animal were such as would be best explained by impairment or loss of central vision; for it is well known that when central vision is lost or impaired in man, objects are better seen at a distance than close at hand, and less distinctly when the eyes are immediately converged on them. This is practically the condition seen in this animal. The loss of central vision would thus account for the fact, noted by Schäfer in his animal, that objects were better seen at a distance than near at hand; and that Munk's animal could never place its fingers precisely on any small object held directly in front of its eyes. There was certainly no indication, but the reverse, that the upper portions of the retina were less sensitive than the lateral and lower portions. It appears to me, therefore, that the symptoms resulting from bilateral destruction of the angular gyrus, described by myself, Munk, and Schäfer, are best explained on the supposition that the angular gyri are more particularly related to the area of distinct vision, and, accordingly, with the macula lutea. The facts of disease in man render it necessary to assume that the region of the yellow spot is represented in each hemisphere, though more in that on the

⁷ *Op. cit.*⁸ *Brain*, July, 1888, p. 159.

opposite than on the same side, and the probability is that the area of clear vision is represented mainly in the angular gyrus of the opposite hemisphere.

The retinal relations of the visual centres are not capable of being explained by a simple division of the retinal fields into correlated halves projected on the corresponding side of each hemisphere. For unilateral lesion of the angular gyrus produces a temporary blindness or amblyopia of the opposite eye; while bilateral destruction induces an enduring impairment of visual acuity in both eyes.⁹ The results of my experiments seem to show that the angular gyrus has relations with both eyes. The crossed action, however, is the only one which is clearly demonstrable in the lower animals, but this does not exclude the possibility of some impairment of vision on the same side, not perceptible by tests applicable to them. It is certain that in man affections of the visual centres occasionally produce crossed amblyopia, and not homonymous hemiopia. Not only is this characteristic of the visual disturbances seen in hysterical hemianæsthesia, the pathology of which is obscure, but it has been noticed also in cases of organic disease. Usually, along with the blindness, or great impairment of vision in the opposite eye, there has been some degree of contraction of the visual field of the eye on the same side. I have myself reported several such cases,¹⁰ and Gowers¹¹ has also seen similar instances. A well-observed case of this nature has been recorded by Sharkey.¹² Post-mortem examination revealed softening and absorption of a considerable area of the opposite hemisphere, including the angular gyrus. The occipital lobe was intact, and in no wise reduced in size as compared with the other.

A distinguishing test between tract and central hemiopia has been suggested by Wilbrand,¹³ and advocated by Wernicke and Seguin, which consists in determining whether a pencil of light thrown on the blind side of the retina induces contraction of the pupil or not. As the optic tract is the path of the fibres which excite pupillary contraction through the oculo-motor centres, as well as those which excite visual sensations in the cortex, lesion of the optic tract will cause not only hemiopia, but also paralysis of the reflex reaction of the pupils to light; whereas, lesion of the cortical centres will cause hemiopia, but leave intact the pupillary reaction. This test, however, requires great care in its application, as it is difficult to restrict the rays of light entirely to the blind side. In a case recently under my care at King's College Hospital,¹⁴ in which the dividing line passed through the fixation point, and which was carefully investigated in this relation by Professor McHardy and myself, the pupillary reaction was not obtained, as a rule, when the pencil of light was thrown on the right side of the retina; whereas it occurred readily when the light was thrown on the left half of each retina. These facts, therefore, would corroborate the hypothesis that this was a case of tract hemiopia.

I have recently verified the hemiopic pupillary reaction in two monkeys in which I accidentally severed the optic tract in establishing lesions of the temporal lobe. The result in both cases was absolute hemiopia to the opposite side. In both cases the left optic tract was divided, and in both, along with right hemiopia, there was absence of reaction of the pupil when a fine pencil of electric light was thrown on the left half of each retina; whereas active reaction took place when the light was thrown on the right half. Both in the monkey, and in several cases of hemiopia in man depending on lesions of the hemisphere, I have found that the pupillary reaction is equally well marked whichever side of the retina is illuminated. There can be no question that in man and monkeys there is decussation of the optic tracts in the chiasma. Michel, in his comparatively recent monograph,¹⁵ still maintains the contrary, on the basis of microscopical investiga-

tion; but his results have been attributed by Singer and Münzer¹⁶ to imperfect methods of examination.

In reference to the pathology of crossed amblyopia from lesion of the angular gyrus in the monkey, as well as of similar cases of disease in man, I may here allude to the hypothesis advanced by Lannegrace. Lannegrace regards the eyeball as innervated by two sets of fibres—sensorial, or optical proper, and sensory, on which the proper nutrition of the eyeball depends. The sensorial, or optical, decussate in the chiasma, and are distributed to the occipital lobe; while the sensory decussate in the pons, and, applying themselves to the posterior fibres of the internal capsule, are distributed mainly to the angular gyrus. Lesions of the sensory fibres produce amblyopia and sensory disturbances in the eyeball. A similar result follows lesion of the angular gyrus, and is essentially dependent upon changes which are induced in the nutrition of the eye. This hypothesis would require that in all cases of amblyopia from cerebral lesion there should be impairment of sensation in the eyeball. But this is certainly not the case, for, though in hysterical amblyopia there is affection of common sensation as well as of vision, it is not so in the amblyopia following destruction of the angular gyrus. Though affections of the fifth nerve, which cause loss or impairment of sensation of the eyeball, frequently also lead to trophic disorders of the eye, yet this is not necessarily so; and, even when the eyeball is absolutely anæsthetic, provided that no trophic disturbances have occurred, vision is not in the least impaired. In proof of this I would refer to cases (Cases I and III) reported by Hutchinson in the *Ophthalmic Hospital Reports*, vol. iv, 1863-65. Nor does complete anæsthesia of the eyeball induced by cocaine impair the visual acuteness of the eye.

These appear to me to be fatal objections to the hypothesis advanced by Lannegrace, and I contend that the only hypothesis which seems to harmonise with all the facts is, that the angular gyri are more particularly the centres for clear vision, each mainly for the eye of the opposite side. Whether the other portions of the retina, upper, lower, outer, and inner, are specially represented in corresponding regions of the occipital lobe, according to the hypotheses of Munk and Schäfer, cannot be said to have as yet been established; for, even after the most extensive destruction of the occipital lobes, no portions of the retina appear to be absolutely blind; hence, even if we admit that the effects of irritation probably indicate a special relation of the different portions of the visual field to certain portions of the occipital cortex, the relation, so far as we may judge by the facts of disease or experimental lesion, does not seem to be an exclusive one.

It is true that in man we sometimes find, besides general hemiopic deficiency, partial, quadrant or sector-like, defects in the upper or lower halves of the visual field. These appear, however, to be merely incomplete hemiopia, and occasionally, as in the case which I show you, an islet of subnormal visual acuity may be seen in the defective half. The pathology of these sector-like defects is a matter of conjecture. They have not been conclusively brought in relation with lesions of any particular portion of the cortex, and the probability is that they are dependent rather upon partial lesions of the optic radiations than of the cortical centres themselves. This was without doubt the pathology in the case which I have alluded to, for the defect occurred in a patient who had a sudden attack of hemiplegia accompanied by hemianæsthesia and some affection of speech.

It is doubtful whether there are on record any cases of strictly cortical lesions of the occipital lobe proper, accompanied by hemiopia, apart from direct or indirect implication of the optic radiations. In most of the cases of hemiopia which have been examined after death, in which the optic tracts, optic thalami, or corpora geniculata have not been obviously diseased, the lesions have been found in the medullary fibres of the posterior region, vaguely or inaccurately called the occipital lobe; or, if the cortex has been mainly affected, the lesions have been multiple and diffuse, and not confined to the occipital region. And in addition to hemiopia, there have been hemiplegia, hemianæsthesia, aphasia, or other symptoms of implication of the cerebral tracts and centres beyond those of the occipital region.

Under my direction, my friend and pupil, Dr. Ewens, has collected and analysed the majority, if not all, of the recorded cases of hemiopia (with necropsies) depending on cerebral lesions which have not obviously been of such a character as to cause indirect and indefinite implication of other regions. Of 41 cases of hemi-

⁹ This accords with Gowers's hypothesis that "on the outer surface, in front of the occipital lobe, there is a higher visual centre in which the half fields are combined, and the whole opposite field is represented." (*Diseases of Nervous System*, vol. II, p. 19.)

¹⁰ Cerebral Amblyopia and Hemiopia, *Brain*, vol. III, p. 456.

¹¹ *Diseases of the Nervous System*, p. 19.

¹² *Médecine-Chirurgicale Transactives*, vol. LXVII, 1884.

¹³ *Op. cit.*

¹⁴ The patient was a man, aged 39. Two years before he had contracted syphilis, and at the time of his admission was suffering from a large tertiary ulcer on the soft palate. He had twitching of the right side of the face, together with weakness and numbness of the left side. The left hand grasp was weak, and there was loss of dorsal flexion of the left foot. The tongue deviated to the right on protrusion. He was found to be absolutely hemiopic towards the left side, and a careful perimetric examination by Professor McHardy demonstrated that the dividing line passed exactly through the fixation point.

¹⁵ *Über Sehnerven-Degeneration und Kreuzung*, 1887.

¹⁶ *Beiträge zur Kenntniss Sehnervenkreuzung*, 1889.

of 15, 15 were from disease of the occipito-angular region, 2 were cases of disease of the angular and supramarginal gyri only, 15 were described as being from disease of the occipital lobe alone. Of these 15, there were only 2 (Hun's case¹⁷ and Doyné's case¹⁸) in which there was not either a tumour, cyst, abscess, or softening of the medullary substance of the occipital region, or another lesion affecting the optic thalamus; and in 1 of these cases (Doyné's), the position of the lesion was not accurately described.

In the other cases the lesions were of a diffuse character, 6 being from lesion of the occipito-temporal region, and 3 from lesion of the occipital, temporal, and parietal lobes simultaneously, the angular gyrus being implicated in all.

From the comparative frequency with which hemiopia has been found associated with lesions of the cuneus and its neighbourhood Seguin¹⁹ and Nothnagel²⁰ are of opinion that this portion of the occipital lobe has a special relation to visual perception; while Wilbrand believes that the visual centre is more especially in the apex of the occipital lobe. These hypotheses are not supported by experimental research. The probability is that any apparent relation between lesions of the cuneus and the occurrence of hemiopia, is due to the special proclivity of this region to affection by morbid vascular conditions, and to coincident implication of the optic radiations of the occipito-temporal region. In Seguin's own case,²¹ on which he relies in support of his hypothesis, not only was the cuneus implicated, but also the fourth and fifth temporal gyri and a part of the gyrus hippocampi.²² Cases have also been recorded in which, not only unilateral, but bilateral lesions have been found in the occipital lobes without any affection of vision whatever.

Irritative lesions of the angular gyrus occasionally give rise to optical illusions, or flashes of light, followed by temporary amblyopia, as recorded by Hughes Bennett²³; while destructive lesions of the angular gyrus, more particularly in the left hemisphere, are generally associated with the special form of sensory aphasia termed "word-blindness" (Kusmaul). Word-blindness is not necessarily accompanied by any noteworthy affection of visual sensation, though in some cases, where the lesion of the occipito-angular region is more extensive, there may be a greater or less degree of right hemiopia.

On the other hand, right hemiopia, pure and simple, is not necessarily associated with any defects in visual ideation. This would be an argument against its cortical nature. The fact that visual ideation, more particularly in reference to the association of written symbols with their meanings, is apt to suffer more readily than simple perception, appears to me to illustrate the laws of the evolution and dissolution of the nerve centres, which have been so ably expounded by Hughlings Jackson in his Croonian Lectures delivered here a few years ago (1884). As evolution is from the most simple and most stable up to the most complex and least stable, so destructive processes annihilate first of all the higher, and last of all the lower functional manifestations. The functions of the visual centres in respect to mere visual sensation, or simple presentation, are much more stably organised than those which imply visual ideation or re-presentation, and in particular such highly specialised and complex processes as are involved in the association between visual symbols and things signified. Hence, a lesion of the area of clearest vision may paralyse visual re-presentation, while the simpler function of visual presentation may not be appreciably impaired. In order that this also should be entirely abolished it is necessary that every trace of the given centre should be extirpated. In other words, re-presentative blindness will occur sooner than presentative blindness, and the former more readily in its most specialised modes of manifestation.

In regard to the visual centres of the lower vertebrates, I cannot quote many observations or experiments of my own. The

visual centres of dogs have been the chief subject of physiological investigation. Hitzig²⁴ first noted the occurrence of blindness in the opposite eye from destruction of the occipital region in dogs; and in 1881 Goltz described an affection of vision resulting from destructive lesions of the opposite cerebral hemisphere, which, however, he did not specially associate with lesions of the occipital lobe, though he has more recently admitted this relationship. The affection in question was, in his opinion, not complete blindness, but an inability on the part of the animal to understand or interpret what it saw. To this condition he gave the name *Hirnsehschwäche*, or cerebral amblyopia. It was entirely crossed, and affected only the eye on the side opposite the lesion. Munk, in his first experiments, arrived at essentially the same conclusion; namely, that the affection of vision resulting from lesion at the point A, Fig. 14,

Fig. 14.—Cortical centres of the dog, after Munk. A, Visual area; B, auditory area; C to J, tactile sensory area (*Fühlsphäre*); D, fore-limb region; E, hind-limb region; F, head region; G, eye region; H, ear region; I, neck region; J, trunk region.

occurred only in the opposite eye. Dalton²⁵ also found that the opposite eye was rendered blind, and to all appearance permanently so, when the cortex was destroyed in the region of the posterior division of the second external convolution, which he terms the angular convolution. Luciani and Tamburini, on the other hand, found that destruction of the second external convolution, more particularly of its median or parietal portion, caused blindness of the opposite eye, and also some degree of amblyopia of the eye on the same side. The further experiments of Munk, however, as well as those of Loeb²⁶ and of Goltz,²⁷ and also the later experiments of Luciani,²⁸ appeared to show that though in dogs the visual area is mainly in relation with the opposite eye, it is also in relation with the outer quadrant of the eye on the same side. Hence, destruction of the visual centre in the one hemisphere paralyses the inner three-fourths of the opposite retina, and the outer fourth of the retina on the same side. The condition, therefore—at least the enduring one—is that of homonymous hemiopia towards the opposite side: the defect in the eye opposite greatly exceeding that in the eye on the same side. But the facts recorded by Luciani and Tamburini indicate that, for a short time at least, after the destruction of the middle portion of the second external convolution there is blindness in the opposite eye. And Goltz²⁹ remarks that he does not think that his former conclusions were due to defective observation, but that there was probably some variation in his operative procedure. It is, however, likely that we have here the same relations as exist in monkeys, and that, for the time at least, after complete extirpation of the visual sphere, there is total blindness in the opposite eye. This is confirmed by the experiments of Bechterew, recently published.³⁰ Bechterew finds that in dogs and cats there

¹⁷ *Amer. Journ. Med. Sci.*, 1887, Case i.

¹⁸ *Ophthalm. Soc.*, November 14th, 1889.

¹⁹ *The Journal of Nervous and Mental Diseases*, vol. xiii, January, 1896.

²⁰ *Neurolog. Centralblatt*, 1887, p. 213.

²¹ *Op. cit.*

²² Since this was written a case has been put on record by Delépine (*Trans. Path. Soc. Lond.*, May 20th, 1890) in which right hemiopia was apparently associated with softening of the left cuneus. In this case, however, there was general arterial degeneration, and there were many circumscribed patches of softening in various parts of the brain. In particular there was a small area which had destroyed the greater part of the middle occipital convolution. This case is, therefore, too complex to allow of exact conclusions as to the connection between the hemiopia and the lesion of the cuneus in particular.

²³ *Excessive Sensory Cortical Discharges and their Effects*, *Lancet*, March 30th and April 16th, 1889.

²⁴ *Centralblatt f. med. Wissenschaften*, 1874.

²⁵ *Centres of Vision in the Cerebral Hemispheres*, *Med. Rec.*, 1881.

²⁶ *Pflüger's Archiv*, 1881.

²⁷ *Ibid.*, p. 459.

²⁸ *Sensorial Localisations in the Cortex Cerebri*, *Brain*, vol. 7, 1885, p. 145.

²⁹ *Op. cit.*, p. 48.

³⁰ *Abstract in Neurolog. Centralblatt*, April, 1890.

are two regions in the cortex related to vision; the one in the occipito-parietal region, in relation with the corresponding halves of both retinae; the other, more especially in the parietal region, in relation with the opposite eye alone. Lesion of the former causes homonymous hemiopia; lesion of the latter, generally, possible only in association with the former, causes, along with hemiopia, amblyopia of the opposite eye by paralysing the centre of clear vision. This combined affection usually after a time gives place to homonymous hemiopia; or, on the contrary, the hemiopia disappears and the crossed amblyopia remains. Bechterew's conclusions may serve to explain, among others, the results arrived at by Gilman-Thompson and Sanger-Brown,³¹ which appear to be entirely at variance with those of Munk, Goltz, and most other physiologists. For they find that lesions, of sufficient size and depth, in the posterior part of the occipital region in cats and dogs, invariably cause blindness of the opposite eye, with no impairment of vision in the eye of the same side. These authors, however, seem to think that the extent of the visual sphere is a matter more of cubical capacity than accurate anatomical localisation; for they say that in order that the blindness should be permanent, between 2.5 and 3 cubic centimetres of brain tissue should be removed in cats; and between 4.5 and 6 cubic centimetres in dogs. To render the blindness permanent, the incision must be at least 0.5 centimetre deep, and 2 centimetres in diameter, in cats; and 1 centimetre deep, and 3 centimetres in diameter, in dogs; and it must involve at least two convolutions. Smaller lesions produce complete blindness of the opposite eye, lasting from a day or two to six weeks. They conclude from their experiments that in cats and dogs there is complete decussation of the optic nerves in the chiasma. This is, however, opposed by the researches of von Gudden,³² which show that in dogs and cats there is partial decussation of the optic tracts; and Nicati³³ found, experimentally, that division of the chiasma in the antero-posterior, or sagittal diameter, did not cause complete loss of vision in either eye. The recent researches of Singer and Münzer, previously alluded to, indicate that there is only partial decussation in the chiasma of the cat, dog, and also in the rabbit.

The exact limits of the visual sphere in dogs are still the subject of some differences of opinion, but all the experiments agree in including in this area the posterior half of the second external convolution. This is the convolution which in its electrical reactions corresponds with the angular gyrus and occipital lobe in monkeys. The visual area, as defined by Munk, is represented in the accompanying figure (Fig. 15). Point A, situated chiefly in the posterior division of the second external convolution, he regards as the centre of clear vision (macula lutea) of the opposite eye. The mesial portion of the visual sphere adjoining the falx he regards as the centre for the inner half, the anterior portion for the upper half and the posterior portion for the lower half of the opposite retina. The lateral portion he regards as the centre for the outer quadrant of the eye on the same side. Destruction of each portion he states induces blindness in the respective region of the eye on the opposite or same side accordingly, and it is only by abnormal fixation of the eyes, or by practice, that the animal is able to overcome the defects so induced.

Munk describes, as the effects of extirpation of a circular area of the cortex in region A, measuring about 15 millimetres in diameter and 2 millimetres in thickness, a condition of vision, or visual perception, similar to that already defined by Goltz. The animal is not blind, inasmuch as it is able to avoid obstacles, but it appears to have lost all visual ideation. To this affection he gives the name *Seelenblindheit* or "psychical blindness," in contradistinction to *Rindenblindheit* or "cortical blindness," which implies total loss of vision presentative, as well as re-presentative. In explanation of this condition he propounds what appears to me a somewhat crude hypothesis, viz., that extirpation of the region in question has removed all the visual pictures which are stored up in and around the spot, and that it is only by a process of education that the animal again acquires a new stock of pictures which are deposited in the undestroyed portion of the visual sphere. Some pictures, however, apparently less fragile than the rest, may escape the general destruction occasioned by this iconoclastic lesion. In one case it is the picture of the dish out of which the animal has been accustomed to drink; in another it is the sign to "give the paw," which the animal has been accustomed to obey.

Goltz has criticised this hypothesis in the following amusing terms:—

"A considerable portion of the cortex of the occipital lobe is described as the visual area by Munk. By far the larger portion of this area, however, is, according to him, pure *luxus*. The memorial pictures (*Erinnerungsbilder*) of the visual perceptions are huddled together like sheep in a storm, in a narrow spot which occupies only about two-sevenths of the whole visual area. When this small spot, which corresponds to the macula lutea of the human retina, is destroyed on both sides the animal is at first blind, and only gradually learns to see, like a puppy, with the aid of the rest of its visual sphere. Five-sevenths of the visual sphere—a large portion of the cortex—appears retained in order that a dog which falls into the hands of the physiologist should again learn to see, when its accumulated visual pictures are cut out. All dogs which escape this fate—and these, since the creation of the dog, must be very many—carry during their life five-sevenths of their visual sphere as an uncultivated fallow field. A wonderful thing in hypotheses!"³⁴

Fig. 15.—Relations of the eyes to the visual area in the dog (after Munk).

Even if it were the case that the different portions of the retina are represented in the indicated regions of the visual area, it is improbable that these could be determined with any degree of certainty except by exact perimetric investigation, which is naturally impossible in the lower animals. The difficulties of deciding questions of this kind in the lower animals are illustrated by Munk's account of his experiences with rabbits.³⁵ "I had at least believed that I could determine with which eye the rabbit saw better, and with which it saw worse. In this, however, I have been mistaken, because it occasionally happened to me that where

³¹ *Researches of the Loomis Laboratory*, 1890.

³² *Arch. v. f. Ophthalmologie*, 1874, Band 20.

³³ *Archives de Physiologie*, 2nd Series, Tome 5, 1878.

³⁴ *Op. cit.*, p. 175.

³⁵ *Sitzungsberichte Akad. d. Wissensch. zu Berlin*, vol. xxxi, June 20th, 1889, p. 631.

from tests I had thought I had made out that the greater imperfection of vision existed in the left eye, *post-mortem* examination revealed the fact that the left tract and the right optic nerve were more atrophied than the right tract and the left optic nerve."

Loeb, after a series of carefully devised experiments, concludes that there is no foundation for the views of Munk that particular segments of the retina are in special relation to definite regions of the visual area. When defect of vision occurs from lesion of the posterior lobe, it is always of the same hemiopic or hemiambyopic character, whatever portion of the visual sphere be injured. The lateral portion of this sphere is not in special relation with the outer quadrant of the eye on the same side, nor is any portion more in relation with one part of the opposite retina than another. In particular, central vision is precisely that which is least affected in all cases, whether of unilateral or bilateral lesion of the visual zone. There is never any eccentric or abnormal fixation of the eyeballs when the special regions indicated by Munk are destroyed, such as would necessarily result if the corresponding portions were paralysed, nor is the recovery of vision, after partial lesions of the visual area due to practice, or to the acquisition of new visual experience, inasmuch as recovery takes place when the animal is kept absolutely in the dark, and thus prevented from exercising its visual faculties.

In rabbits the visual centre would, according to the homology of the electrical reactions, occupy the parieto-occipital region of the hemisphere. The exact limits of the visual zone of these animals do not appear to have been accurately determined by any observer, though certain experiments of Moeli³⁶ point to lesions of the region indicated as causing, at least, temporary blindness of the opposite eye. It has been supposed that in this animal there is complete decussation of the optic tracts in the chiasma, inasmuch as the experiments of Brown-Séquard have shown that sagittal division of the chiasma causes complete loss of vision of both eyes. The total decussation in the chiasma of the rabbit was also supported by the earlier researches of von Gudden, who found that after enucleation of one eyeball the opposite optic tract only became atrophied.³⁷ But, in his later researches, he concluded that a small fascicle of uncrossed, or direct, fibres exist also in the optic tract of this animal, similar to that seen in higher vertebrates. Singer and Münzer are also of opinion that there is only partial decussation in the chiasma of the rabbit, but the uncrossed tract does not run as a separate bundle, but as fibres more or less diffused throughout the optic tract. In the mouse and guinea-pig, however, the decussation is a complete one. The partial decussation of the optic tracts in the chiasma would favour the opinion that, in the rabbit also, both eyes are more or less in relation with each visual zone; and certain experiments of Munk would seem to favour this notion. The point, however, is one which requires further investigation.

In pigeons, and in birds in general, the region which in its electrical reactions is homologous with the visual centre of the higher animals occupies the parieto-posterior aspect of the hemisphere, where it forms a thin lamina over the corpus striatum. McKendrick³⁸ found that destruction of this region caused blindness in the opposite eye; whereas removal of the anterior part of the hemisphere had no effect on vision, nor removal of the posterior extremity of the hemisphere. Similar results have been obtained by Jastrowitz³⁹ and Musehold.⁴⁰ Blaschko, however, found that vision did not seem entirely abolished in the opposite eye by destruction of the cortex in the region indicated; and Munk came to the conclusion that though vision at first seems entirely abolished in the opposite eye, yet, after a time, it is regained in the extreme outer or lateral portion of the retina.

It is usually stated that in pigeons a complete decussation of the optic tracts occur in the chiasma, but von Gudden expresses some doubts on this point. Singer and Münzer, however, believe that in the pigeon a total decussation occurs. Munk quotes, in favour of his conclusions, certain observations by Müller of the effect that in the retina of the pigeon there is, besides the usual fovea centralis, another fovea, situated nearer the temporal region of the retina. The outer fovea would subserve binocular, and the central fovea monocular vision. These statements have been supported by the ophthalmoscopic investigations of Hirschberg.

It has seemed to me that if any bird can possess binocular vision it should be the owl, whose eyes are placed almost in the same plane. To decide this question I recently completely extirpated the right hemisphere of an owl. The right eye was then securely closed. The owl reacts very readily to visual tests, and is keenly alive to every movement coming within its field of vision. This bird, however, for ten days at least, remained perfectly indifferent to the electric light flashed in its eye, to all kinds of threats, and when urged to move flew blindly against every obstacle in its course. At the end of this time there were indications of vision, which were found, however, to depend on the partial occlusion of the right eye. In order to ascertain if the visual centre of the left hemisphere was undamaged, the right eye was completely freed from its closure. This had the effect of restoring the animal's sight, so far as the right eye was concerned, though no indications of vision could be made out in the left eye. The bird was able to pursue and ultimately catch a mouse introduced into its cage, though the mouse frequently escaped for the time by getting to the owl's left. The right eye was then removed. It then speedily became apparent that the animal was not entirely blind, but could see towards the right with the outer portion of its left eye. It noticed and winced at threats made towards the right, came forward and pecked at pieces of meat held in this position, though its aim was not very accurate, and one day pursued about the cage and ultimately, after considerable difficulty, captured a mouse, which it devoured whole. No doubt can therefore be entertained as to the binocular relations of each cerebral hemisphere in the owl. It is stated, however, by Michel, as well as by Singer and Münzer, that there is total decussation of the optic tracts in this bird. If this be correct, it follows that total decussation of the optic tracts is not inconsistent with binocular representation in each cerebral hemisphere.

My own experiments, as well as those of Munk, Horsley, and Schäfer, show that when the lesions are strictly limited to the visual sphere, vision alone is affected or abolished, without any implication of the other forms of sensibility, general or special, and absolutely without any motor paralysis. The contrary results obtained by some authors are without doubt dependent on primary or secondary injury to other sensory or motor tracts or centres. In Goltz's experiments the affections of vision from injury of the occipital regions appear to have been almost invariably associated with other forms of sensory disturbance; but the manner in which he established his lesions has not been sufficiently definite as to exclude implication of the sensory tracts of the internal capsule, or other sensory regions of the cortex. Whether after destruction of the whole visual sphere in the higher animals, man and monkey, any form of reaction to retinal impressions, beyond that of the pupil, may continue—as has been contended for by Goltz in the case of dogs, and by Luciani and Tamburini, and Lannegrace even in the case of monkeys—is not supported by clinical investigation, or by my own experiments, or those of Munk on monkeys. Though the monkey, rendered blind by total extirpation of its visual centres, acquires the power of avoiding obstacles when left amidst its usual surroundings, yet this appears to be due rather to a sharpening of its other faculties, or more attentive appreciation of the impressions made on these by the objects with which it is surrounded, than to visual sensation. The question is, however, one which may well bear further investigation; for, if retinal impressions are co-ordinated with apparently purposive actions in the subordinate centres of the lower vertebrates, such as fishes, reptiles, and birds, there is at least the possibility that similar reactions may be discoverable in the higher animals, even though in a much less degree. It is certain, however, that the visual area of the cortex is not a merely functionally differentiated region capable of replacing, or of being replaced by, other cortical regions, inasmuch as destruction of the visual centres leads to atrophy in the primary optic centres, optic tracts, and optic nerves; and, conversely, destruction of the optic radiations leads to atrophy strictly confined to the regions included within the visual zone. The differentiation of an area exclusively—so far at least as can be judged from clinical and experimental results—would strongly favour the hypothesis that the other sensory faculties are also separately localised in definite cortical regions.

A TELEGRAM from Cairo says a small-pox epidemic has broken out in several villages in Egypt. The Government has granted a sum of £2,000 to the sanitary department for vaccinating purposes.

³⁶ *Archives de Physiologie*, 1871-72: Sur les Communications de la Rétine avec l'Encéphale.

³⁷ *Archiv f. Ophthalmologie*, Bd. 20, 1874.

³⁸ *Trans. Roy. Soc. of Edinburgh*, January, 1873.

³⁹ *Archiv f. Psychiatrie*, Bd. vi, 1876.

⁴⁰ *Das Sehcentrum bei Tauben*, August, 1878.