rence of very great rarity; in only one of the 54 cases of fatal injury is it recorded, and then it was through a fracture of the middle fossa. Indicating as it does a most severe injury to the base as well as to the brain, it is not surprising that such cases have usually had a fatal ending. There are, however, instances on record in which its escape from the ear or from the nose has been observed, and yet recovery, apparently complete in every respect, has ensued. I find an account given of the occurrence of the latter not followed by a fatal issue reported by Mr. Luther Holden—a compound fracture of the skull in a man of 40, in whom there was an escape of cerebral matter from the wound and through the nostril. The fracture, extending over the margin of the orbit, had involved the frontal sinus and thus allowed the escape of a portion of the brain through the right nostril on the day following the injury. Dr. Lockwood²⁰ reported a case in which a loss of cerebral substance from the ear followed a fall on deck. The patient recovered.

THE CROONIAN LECTURES ON CEREBRAL LOCALISATION.

Delivered before the Royal College of Physicians of London.

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LECTURE V.

MR. PRESIDENT AND GENTLEMEN.—Followed upwards in their course to the brain, clinical and pathological investigation would appear to show that in the medulla and pons the sensory tracts run in the fillet, or formatio reticularis. Those tracts—namely, the posterior external and posterior median—which do not decussate in the cord, decussate through the nuclei graciles and cuneati into the inter-olivary layer, and thence into the fillet and reticular formation (Edinger). Higher up, the evidence is in favour of the continuation of these tracts in the tegmentum of the crus cerebri, and thence into the posterior part of the internal capsule, whence they radiate outwards, according to Flechsig, and distribute themselves to the cortex in the region lying between the fissure of Rolando and the occipital lobe. It has been supposed by Meynert that the outer third of the foot of the crus is the path by which the sensory tracts of the spinal cord pass into the internal capsule; and in favour of this view is the fact that descending degeneration, while frequently found in the other fibres of the foot of the crus, has not usually been found here. Bechterew and Rossolymo,¹ however, have reported cases of degeneration of this part of the crus apparently in relation with lesion of the temporal and occipital lobes, and it is held by Flechsig that these fibres do not enter the internal capsule, but bend downwards and outwards to radiate in the cortex of the occipital and temporal regions. They are supposed to connect these regions with the cerebellum through the intermediation of the grey matter of the pons, but this is a point which, I think, stands in need of further investigation. In order, if possible, to throw light on the functions and connections of this part of the crus, I have recently divided it in three monkeys. The operation is a somewhat severe one, but the crus can be comparatively easily exposed to view after removal of the lower portion of the temporal region. In all three animals the lesion was satisfactorily established, but none of them recovered sufficiently from the operation to enable me to make altogether reliable observations. But in none of them was there total loss of reaction to sensory stimulation, or greater impairment than could be accounted for by the cerebral lesion. So far as they go, therefore, the experiments are opposed to the view that the outer third of the foot of the crus is the path of the sensory fibres from below.

That the sensory tracts lie distinct from the motor in the posterior division (or rather posterior third of the posterior segment) of the internal capsule has been amply proved by the experiments of Veyssière² and by the researches of Charcot, etc., on cerebral

hemianæsthesia occurring in man. The sensory tracts being admittedly distinct from the motor in the internal capsule, the question then arises whether these, which up to this point have maintained their separate position, fuse in the cortex with the motor, —as some believe—or are distributed to a special region.

In my earlier researches I had observed that tactile and common sensibility appeared to be entirely unaffected, notwithstanding the most extensive lesions of every portion of the convex aspect of the hemisphere, but I noted in several instances in which the destructive lesions extended deeply into the temporal lobe that sensibility became impaired or abolished on the opposite side of the body. Careful *post-mortem* examination showed that in all these cases the hippocampal region (including cornu ammonis and gyrus hippocampi) was more or less extensively invaded. These facts pointed to the hippocampal region as being the centre of common sensibility, and I therefore devised experiments by which I might reach and destroy this region by itself. On account of its deep-seated and concealed position this is, however, practically impossible, and it therefore can only be reached by methods which involve a greater or less extent of injury to the occipital lobe, or the lower temporal region. The effects of lesions of these regions can, however, be allowed for and eliminated, and any further symptoms than can be ascribed to them can be connected with those inflicted on the hippocampal region. The method which I followed in my earlier experiments was to break up and destroy the hippocampal region by means of a wire cautery thrust through the occipital lobe, and directed downwards and forwards in the course of the descending cornu of the lateral ventricle. In this manner I succeeded primarily or secondarily in entirely destroying the hippocampal region and its medullary connections without inflicting injury on the crus cerebri or neighbouring structures. The diagram before you³ is an accurate representation of the superficial appearance of the lesion in one of these cases, and the track of the sinus made by the cautery. The result of this operation was anæsthesia and analgesia of the opposite side of the body, there being total or almost total absence of response to any kind of sensory stimulation. The limbs were not paralysed as to motion, but they appeared to be used with difficulty and awkwardness, and the feet tended constantly to slip off the perch when the animal shut its eyes and went to sleep. In none of my earlier experiments were the animals allowed to live for any length of time, as I considered it necessary to kill them as soon as the symptoms were clearly defined in order to avoid complication by secondary extension of the lesion, antiseptic surgery not being at this time in vogue. The lesion in this case was shown⁴ to be strictly limited to the hippocampal and occipito-temporal region, and without any implication whatever of the internal capsule or crus cerebri. These experiments did not furnish any data towards the determination of the permanency of the symptoms, but they were sufficient to indicate a region, if not the whole region, related to the tactile, common, and apparently the so-called muscular, sensibility of the opposite side of the body.

I renewed my investigations on this subject at a later date⁵ in conjunction with Professor G. F. Yeo. The method of performing the experiments was partly the one I had previously followed, namely, the destruction of the cautery, and partly that of cutting in towards the hippocampal region from the convex aspect of the temporo-sphenoidal lobe. Ten experiments in all were performed, and in five of these in both hemispheres. The result of this series of experiments confirmed in every particular those I had already arrived at, and showed that tactile sensibility was in every case impaired or abolished, in proportion to the destruction of the hippocampal and inferior temporal region. Unfortunately, none of the animals in which the destruction was complete, and the anæsthesia absolute, survived many days, so that the question of duration still remained unsolved. But it was established that a very extensive lesion might be made in one or both hippocampal regions without producing permanent anæsthesia. I need not enter into the details of all these experiments. The two following will suffice.

In one experiment⁶ the left hemisphere was exposed and the whole of the inferior temporal convolution and hippocampal region were severed and scooped out, the lesion being such as to leave only the internal margin of the gyrus hippocampi with the

²⁰ *American Journ. Med. Sci.*, 1859, p. 254.

¹ *Neurolog. Centralblatt*, No. 7, 1886.

² *Recherches Cliniques et Experimentales sur l'Hémianesthésie de Cause Cérébrale* 1874.

³ See Fig. 105, *Functions of the Brain*, p. 329.

⁴ See Figs. 107 and 108, *Functions of the Brain*, p. 331.

⁵ *Phil. Trans.*, Part II, 1884, Experiments XXIV to XXXIII, Figs. 103 to 181.

⁶ Experiment XXVII, Figs. 125, 132, *op. cit.*

tænia semicircularis and the fimbria of the fornix intact. Only a portion of the hippocampal gyrus included between the calcarine and collateral fissure (lingual lobule) remained. The result of this experiment was most marked. There was on the right side complete insensibility to thermal stimulation of such intensity as to cause the most lively signs of sensation on the left side, and total insensibility to every form of mere tactile stimulation, such as touching, gentle pricking, rubbing etc. The limbs were capable of being freely moved volitionally, but they were planted with great awkwardness and uncertainty as to position. While the animal was resting quietly with its eyes shut, I drew the right arm away from its side, of which fact it seemed unaware until it tumbled over. It was keenly sensitive to every form of stimulus, however slight, on the left side. Hearing was unimpaired in both ears; vision, however, seemed somewhat indistinct, though not abolished, towards the right. (This is an important fact in relation to the occurrence of hemiopia from lesion of the occipito-temporal region discussed above.) There was anaesthesia of the right nostril. The symptoms remained unchanged on the second day after the operation, the animal being otherwise in apparent good health, but on the third day it died suddenly of secondary hæmorrhage. A series of microscopic sections of the brain showed that, with the exception of the injuries, above described, in the inferior temporal and hippocampal region, the basal ganglia, crura cerebri, and other structures were perfectly intact.

In another animal a similar lesion was established, involving almost complete detachment of the hippocampal and lower temporal region from the rest of the hemisphere. In this animal there was at first almost, if not total, analgesia, and absolute anaesthesia to all gentle forms of tactile stimulation over the whole of the right side of the body. Hearing was unimpaired, but vision was somewhat defective towards this side, the animal appearing to have some degree of uncertainty as to the position of things offered it on the right front. The condition remained practically unchanged on the third day, when the animal had a slight right-sided fit, indicative of some irritation, found after death to be slight recurrent hæmorrhage. After this the analgesia became absolute, and no sign of perception could be obtained to any form of tactile stimulation. There was also total insensibility to tickling of the right nostril. A similar stimulation of the left caused active grimaces and signs of uneasiness. The animal could move its limbs freely and lay hold of objects firmly with the right hand, but it continually fell over on the right side, owing to the awkward and uncertain manner in which it planted its limbs. Death occurred on the fourth day. The lesion was found accurately limited to the lower temporal and hippocampal region of the left hemisphere without the slightest implication of the crus or basal ganglia. These experiments proved that the various forms of sensation embraced under the term common or tactile sensibility, including cutaneous, muco-cutaneous, and muscular, are capable of being profoundly impaired, or altogether abolished, for the time at least, by destructive lesions of the hippocampal region, and that the degree and duration of the anaesthesia varied with the completeness of destruction of the region in question.

The subject was next taken up by Horsley and Schäfer,⁷ who, so far as I am aware, are the only physiologists who have repeated my experiments in this direction.

Horsley and Schäfer were at first unable to corroborate my observations, but I was able to demonstrate to them that this depended on the incompleteness of their excisions of the hippocampal region, and I assisted them in some of the experiments which they further prosecuted with excellent effect. In one animal in which the hippocampal region was removed there was on the following day partial analgesia, and complete insensibility to mere contact on the opposite side. Death, however, occurred on the second day, so that no conclusions as to duration were possible in this case.

In a second experiment, the hippocampal region was again removed, and the incisions made so as to detach also the margin of the calcarine fissure and hippocampus minor. This animal was profoundly anaesthetic on the opposite side, but there did not appear to be absolute analgesia. All mere tactile stimuli, however, like touch, scratching, rubbing, gentle pricking, were absolutely unperceived, while similar stimulation on the other side at once attracted attention. Tactile anaesthesia continued for several weeks without appreciable alteration, but a gradual improvement occurred, so that examination at the end of six weeks revealed

only some degree of impairment, as evidenced by less easily excited attention by gentle pricking, rubbing, etc., of the side opposite the lesion, as compared with the other. Severe pricking, pinching, or pungent heat, however, appeared to be well perceived. The gradual diminution of the anaesthesia, at first induced by extensive, if not complete, removal of the hippocampal region, led me to suggest similar experiments on the gyrus fornicatus, on the ground that the tactile centre might extend into the rest of the falciform lobe, of which the hippocampal region was only a part. This originated their experiments on the gyrus fornicatus, which proved the accuracy of Broca's anatomical views as to the unity of the falciform lobe, and demonstrated that lesions of the gyrus fornicatus caused similar symptoms to those produced by destruction of the hippocampal region, of, perhaps, even greater intensity and longer duration. In one of the experiments at which I assisted the animal in which, some weeks previously, the hippocampus had been removed, and which had completely recovered from any anaesthesia which might have existed immediately after the operation, the same hemisphere was again exposed and the region of the longitudinal fissure and the gyrus fornicatus excised along the whole length of the corpus callosum. The effect of this operation was to cause absolute analgesia on the opposite side, continuing several days after the operation, as well as complete insensibility to all milder forms of tactile stimulation. The analgesia diminished somewhat as time went on, but six weeks after the operation it was still manifest in some degree. The tactile anaesthesia was, however, apparently in no wise improved, all gentle forms of tactile stimulation being absolutely unperceived. The animal was in perfect health, and exhibited no indications of motor disorder; though, directly after the operation, there was slight weakness of the opposite leg, owing to the injury to the postero-parietal lobule and neighbourhood during the operations necessary to expose the gyrus fornicatus.

Many other experiments were made by Horsley and Schäfer, and recorded in their memoir in the *Phil. Trans., sup. cit.*, and they sought also to determine whether there were any parts of the limbic or falciform lobe especially relating to particular regions of the opposite side. They conclude from their experiments: "We have found that any extensive lesion of the gyrus fornicatus is followed by hemianæsthesia more or less marked and persistent. In some cases the anaesthetic condition has involved almost the whole of the opposite side of the body, in others it has been localised to either the upper or the lower limb and to particular parts of the trunk, but we have not yet succeeded in establishing the relationship between special regions of the body and the parts of the convolution which have been destroyed. Moreover, the anaesthesia was frequently very pronounced and general during the first three or four days after the operation, and, indeed, in several instances took the form of complete insensibility to both tactile and painful impressions, so that even a sharp prick or the contact of a hot iron would produce no indication of sensation, but after that time this general condition would become gradually in great part recovered from, or more localised in definite regions. In all cases, however, in which the diminution of sensibility was well marked during the first few days, it has persisted, although with lessened intensity, for many weeks in those instances in which the animals have been preserved for so long. In other cases, in which apparently the lesion was slight, the diminution of sensibility, although at first well marked, subsequently disappeared entirely. In some instances the hemianæsthesia took the form of inability (or diminution of ability) to localise the seat of irritation, whilst in one case, in which diminution of sensibility was exhibited in a very striking manner, the irritation, when rendered sufficiently intense for the monkey to become conscious of it, was responded to by the animal scratching a different part of its body from that to which the stimulus was applied."

Fig. 40^a represents the condition of the right hemisphere of an animal in which the lesion indicated produced at first complete analgesia, followed by partial anaesthesia, lasting for ten weeks, at which time the animal died from an operation on the left. Fig. 42^b represents the brain of an animal in which the anterior two-thirds of the left gyrus fornicatus were removed. For a few days there was complete analgesia. A week after the operation the condition was much improved, and at this time there was reaction over the whole of the right side to painful impressions, but often want of localisation of the seat of these

⁷ Functions of the Cerebral Cortex, B. 20, *Phil. Trans.*, 1888.

^a *Op. cit.*

^b *Op. cit.*

impressions, a totally different part being scratched from that which was stimulated.

Recovery gradually proceeded, so that after a time the difference of sensibility of the two sides was hardly perceptible, except about the arm and shoulder and in the foot. Eleven weeks after the first operation the right gyrus fornicatus was exposed and injured by scratching its surface with a needle. This, however, produced no perceptible result, and after a fortnight the animal was killed. Fig. 43¹⁰ represents the brain of a monkey in which the posterior part of the left hippocampal gyrus was destroyed. The result was great diminution of reaction to tactile and painful stimuli over the posterior part of the right side of the body, with slight diminution over the whole side.

It is not unlikely that, besides representing sensibility of the opposite side of the body generally, certain parts of the falciform lobe may represent more particularly the sensibility of special regions. But, though I occasionally noted in my experiments on the hippocampal region—like Horsley and Schäfer in their experiments in the gyrus fornicatus—that it seemed as if one region had been more affected than another, yet this was at times not apparent, and in general the anæsthesia has affected the whole of the opposite side, face, arm, leg, and trunk. Evidence is, therefore, so far, not conclusive of the existence of any altogether specialised centres in this general area. It is probable, however, that a certain degree of localisation may be established through the associating fibres, which undoubtedly connect this region with the motor centres of the cortex.

It has not yet been found possible to produce total persistent loss of all forms of tactile and common sensation on the opposite side after destructive lesions of the falciform lobe, but this may be due to the fact that this lobe has never been absolutely destroyed throughout its whole extent. It is probable, however, that common sensibility may, to some extent at least, be bilaterally represented, so that a certain amount of compensation may be effected by the falciform lobe of the other hemisphere. The paths of connection between the falciform lobe and the sensory division of the internal capsule have not yet been traced by any anatomist, but in view of the proofs which have been above given of the relation between the falciform lobe and tactile and common sensibility, it is obvious that the hypothesis of Flechsig as to the distribution of the sensory tracts in the parietal lobe, requires amendment. No scheme of the cortical distribution of the sensory tracts can be admitted as correct which does not connect them with the cortex of the callosal and hippocampal convolutions. Though the gyrus fornicatus appears to be a purely sensory region, and, therefore, one destruction of which should not give rise to centrifugal degeneration in the spinal cord, France¹¹ has found, apparently in relation with destruction of the gyrus fornicatus, secondary degeneration of the pyramidal tracts of the crus cerebri and spinal cord. It is, however, to be noted that in most, if not all, of the cases in which the gyrus fornicatus was destroyed, either the marginal gyrus or neighbouring motor centres and tracts were also more or less implicated, and the suspicion arises that the descending degeneration is in reality due to this cause. France, however, believes that the degeneration occupies a different region of the pyramidal tract from that resulting from lesion of the marginal gyrus alone, being in the latter case towards the posterior and outer part of the crossed pyramidal tract, in the former occupying the whole sectional area of the same.

These considerations are not, however, sufficient to remove all doubts; and these are emphasised by the fact that lesions of the hippocampal division of the falciform lobe, sufficiently far removed from the motor centres and tracts as to ensure their freedom from injury, lead to no degeneration of the pyramidal tracts. The question is one which requires further investigation.

OLFACTORY AND GUSTATORY CENTRES.

The position of the olfactory centre, or at least its principal portion, may with great probability be inferred from the cortical connections of the olfactory tract, altogether apart from physiological experiment. The chief and, in man, the only constant connection of the olfactory tract with the hemisphere is the so-called external root, which passes outward across the anterior perforated space to the cortex of the hippocampal lobule, or anterior and lower extremity of the hippocampal gyrus (see Fig. 26, *Trol.*).

Owing to the original formation of the olfactory bulb and tract as a diverticulum from the anterior cerebral vesicle, the cavity of which has become almost entirely obliterated, the remnants of its original connection with the mesial, external, upper, and lower aspects of the cerebral hemisphere are still spoken of as roots of the olfactory tract. Though in man and the monkey all the said roots, except the external one, are practically obliterated, yet in other animals, in whom the sense of smell is largely developed,

Fig. 26 (after Obersteiner).—*Pp*, pes pedunculi; *Cm*, corpus mammillare; *Tbc*, tuber cinereum; *Ttl*, tractus opticus; *ch*, chiasma; *Il*, nervus opticus; *T*, temporal lobe; *U*, uncus; *Am*, nucleus amygdalæ; *Spa*, substantia perforata anterior; *Lt*, lamina terminalis; *Coa*, anterior commissure; *Pspl*, pedunculus septi pellucidi; *Slm*, Sulcus medius subst. perf. ant.; *Rec*, rostrum corporis callosi; *Gcc*, genu corporis callosi; *Nl*, nervus Lancisii; *M*, longitudinal fissure; *F*, frontal lobe; *Bol*, bulbus olfactorius; *Trol*, tractus olfactorius.

four roots are usually described, namely, an external root passing to the hippocampal lobule; a superior and middle root, connecting the tract respectively with the grey matter of the base of the frontal lobe and the trigonum olfactorium, or grey matter of the anterior perforated space; and an inner root, which appears to fuse with the anterior extremity of the callosal gyrus. The connection of the olfactory tract, by means of its inner and outer root, with the anterior and posterior extremities of the falciform lobe, have been compared by Broca to a tennis racquet, of which the circumference is formed by the falciform lobe and the handle by the olfactory tract and bulb (see Fig. 27).

Fig. 27.—Inner surface of the right hemisphere of the otter (Broca). *O*, olfactory lobe; *H*, hippocampal lobe; *C*, commencement of the lobe of the corpus callosum; *C*, *C'*, *C''*, lobe of the corpus callosum; *F*, frontal lobe; *P*, *P*, parietal lobe; *8*, limbic fissure; *9*, pli de passage rétro-limbique; *10*, subfrontal sulcus; *11*, pli de passage fronto-limbique; *12*, inferior fronto-limbic annectent gyrus; *13*, subparietal fissure.

¹⁰ *Op. cit.*

¹¹ Descending Degenerations which follow Lesions of the Gyrus Marginalis and Gyrus Fornicatus in Monkeys, *Phil. Trans.*, B. 48, 1889.

According to the development of the sense of smell in different animals, the structures above described, or parts of them, undergo great variations. Broca divides all animals into two classes—first, the “osmatics,” a class which includes the great majority of mammals, and, secondly, “anosmatics,” in which the sense of smell is relatively feebly developed, including (primates, amphibious carnivora), rudimentary (balænidæ), or altogether wanting (delphinidæ). In the osmatics, as you may see in the specimens before you, the olfactory bulb and tract are large, and the hippocampal lobule in particular attains extraordinary proportions, and, in some animals, constitutes the greater portion of the cerebral hemisphere. In the anosmatics the hippocampal lobule is relatively small in those—such as in man and monkey—in which the sense of smell, though good, is subordinate to other sensory faculties; while in the balænidæ it is greatly reduced, and in the delphinidæ is almost entirely wanting. The posterior boundary of the hippocampal lobule is in the osmatics clearly indicated by an annectent gyrus, which interrupts the continuity of the limbic fissure and unites the lobule with the parieto-temporal part of the hemisphere. It is termed by Broca the *pli de passage rétro-limbique* (see Fig. 27, 9).

In man and the monkey the homologue of this gyrus is usually considered to be the pedunculus cunei or cuneo-limbic annectent gyrus (see Fig. 28, *PCu*) connecting the cuneus with the hippo-

Fig. 28 (after Obersteiner).—*Ccl*, corpus callosum; *Gcc*, genu of corpus callosum; *Coa*, anterior commissure; *Fcl*, columns of fornix; *Fcr*, crus of fornix; *CAm*, cornu ammonis; *Tf*, tuberculum fascia dentate; *BW*, Balkenwindung (splenial convolution); *I*, isthmus gyri fornicati; *U*, uncus; *PCu*, pedunculus cunei; *Sbp*, sulcus subparietalis; *clc*, fissura calcarina; *Rcc*, rostrum of corpus callosum; *Spcc*, splenium of corpus callosum; *Spic*, septum lucidum; *Fep*, body of fornix; *Fi*, fimbria; *Fd*, fascia dentata; *Stlm*, stria longitudinalis medialis; *g*, gyrus cinguli; *H*, gyrus hippocampi; *Cu*, cuneus; *ccl*, sulcus corporis callosi; *poc*, fissura parieto-occipitalis; *oti*, sulcus occipito-temporalis inferior.

campal gyrus. Beauregard,¹² however, places it in the brain of the whale at the extremity of the temporal lobe, immediately posterior to the uncus, and Zuckerkandl¹³ assigns it a similar position in the brain of the dolphin.

I am inclined to think, on physiological grounds, that in man also and the monkey the posterior boundary of the hippocampal lobule is to be found in the annectent gyrus which connects the uncus with the anterior extremity of the temporo-sphenoidal lobe (+ Fig. 28). This is well seen in the brain of the chimpanzee which I show you. This would make the hippocampal or pyriform lobule correspond with the gyrus uncinatus, and not with the gyrus hippocampi as a whole, which, as we have seen, is a portion of the tactile centre.

The relatively large size of the internal root in some animals, and its apparent connection with the anterior extremity of the gyrus fornicatus, led Broca to believe that there was a connection between the development of this region and the sense of smell; but the fact, which he himself admits, that the anterior portion of the callosal gyrus is particularly well developed in the brain of the Cetaceans, in which the sense of smell is merely rudimentary, is decidedly opposed to this hypothesis. Zuckerkandl, however, claims that the anterior extremity of the callosal gyrus in the dolphin is in some degree atrophied as compared with that of osmotic animals. The connection of the inner root with the callosal gyrus appears to me to be only superficial, and the probability is that this root really joins with the anterior extremity of

what Zuckerkandl terms the marginal gyrus (*Randwindung*), which forms the callosal margin of the falciform lobe, and is continuous posteriorly with the fascia dentata (see Fig. 28, *Fd*). The dorsal or supracallosal portion of this gyrus is in anosmotic animals almost entirely obliterated, the atrophied remnants constituting the nerves of Lancisi (*Stlm*, Fig. 28), which are visible in man on the superior surface of the corpus callosum. He also describes, as peculiar to osmotic animals, a process of the falciform lobe which projects below the splenium of the corpus callosum, and which he terms the “*Balkenwindung*” (splenial gyrus.) Schwalbe, however, regards this merely as a portion of the gyrus dentatus. It is often seen in man (*BW*, Fig. 28). Zuckerkandl endeavours also to establish a relation between the development of the sense of smell and the size of the hippocampus or the cornu ammonis. He contends that in the dolphin the cornu ammonis is reduced to an insignificant remnant, and maintains in opposition to other anatomists that what has been regarded as the hippocampus, and which, topographically, and in its other relations, corresponds with this structure, is no hippocampus at all, but merely a prominence in the descending cornu of the lateral ventricle, corresponding to the eminentia collateralis of Meckel. Not having facilities for a proper investigation of this point, I requested the opinion of Sir W. Turner. He wrote me as follows:

“I will describe a dissection I have made of the descending horn of the lateral ventricle in the brain of a porpoise. This horn was continuous with the posterior end of the body of the lateral ventricle, and passed forwards and downwards into that lobe of the hemisphere which, from its position, may be called temporo-sphenoidal. It contained a well-defined eminence along its floor which was undoubtedly the hippocampus major. This eminence, 23 millimètres long, swelled out as a club-shaped end anteriorly, which was from 4 millimètres to 5 millimètres in transverse diameter.

Along the inner border of the hippocampus, the posterior pillar of the fornix was attached as the tænia hippocampi. The choroid plexus projected towards the descending horn immediately internal to the tænia hippocampi. The gyrus hippocampi lay in relation to the inner concave border of the tænia hippocampi; it was between 5 and 6 millimètres in breadth, and terminated anteriorly in a lobus hippocampi, the greatest breadth of which was 8 millimètres.”

Sir W. Turner’s dissection is, therefore, opposed to Zuckerkandl’s view as to the absence of the hippocampus in the porpoise. Though the hippocampus is well developed in osmotic animals, it cannot be said to be atrophied in man and in the monkey, or to undergo variations in size with the other parts admittedly in relation with the olfactory tracts. It is questionable whether the hippocampus in man is relatively smaller than that of the lower animals; but, as to its absolute size, Sir W. Turner says: “Possibly the elephant, and it may be the largest whales, possess a hippocampus absolutely as large as that of the human brain, but I am inclined to think that the human hippocampus is absolutely larger than in mammals generally.”

The hippocampal lobule, however, is relatively much smaller in man than in the osmotic animals, and perhaps is absolutely smaller than in many of them. What are the conditions which lead to variations in size of the hippocampus¹⁴ cannot be said to be clear, but there appears to be an inverse ratio between the size of the gyrus fornicatus and gyrus hippocampi. This is so in the Cetaceans and Delphinidæ, in which the gyrus fornicatus is unusually large and more richly convoluted than in the higher animals. So, also, in the osmotic animals generally, the gyrus fornicatus is relatively larger than the gyrus hippocampi (apart from the hippocampal lobule). In the kangaroo the gyrus hippocampi and hippocampus merge with the gyrus fornicatus, and the hippocampus appears as the inrolled edge of this gyrus (see Fig. 29). This indicates a functional community between the hippocampus and the rest of the falciform lobe, which we have seen is related to the general sensibility of the body.

By means of the anterior commissure (olfactory division) the olfactory bulbs and tracts are connected with each other. This connection is best seen in those animals which have large olfactory bulbs (see Fig. 30, *po*), but a similar connection can also be traced in the brain of the monkey and the man (see Fig. 31, *ac*). The anterior commissure also connects the hippocampal lobules together (Fig. 30, *pt*). This division of the anterior commissure (temporal division) does not altogether vary in size with that of

¹² Sur l’Encéphale des Balanides.

¹³ Ueber das Riechcentrum, 1887.

¹⁴ In my experiments on the hippocampal region, it was not possible to distinguish between lesions of the hippocampus apart from those of the gyrus hippocampi.

lobes on both sides. They say, page 324, "Animals with the antero-inferior portion of the lobe, including the subiculum, completely cut away, smell their food, immediately detect a malodorous substance, such as aloes or assafoetida, with which it (that is, the raisin) may have been smeared, and cast it aside without tasting. A raisin into which quinine has been inserted is smelt, eagerly bitten, and immediately rejected with expressions of disgust." On looking at the figures which accompany their paper, however, I can see only one (No. 2, Plate 4) in which the anterior extremity appears to have been completely removed. In all the other portions of the hippocampal lobule are still to be seen on both sides.¹⁹ In the notes referring to the experiment No. 2, I do not see any reference to tests of the animal's sense of smell, but it is stated that on the second day it gave clear indications of retaining its sense of taste unimpaired. But as to the others, sufficient I think is left of the hippocampal region on both sides to permit of the sense of smell being retained, even if not so acutely as before. I have, therefore, thought it desirable to make some new experiments in reference to this point.

I have in three monkeys removed the anterior portion of the temporal lobes by successive operations, but only one of the animals survived the double operation sufficiently long to allow of any satisfactory observations being made. In this case the anterior part of the left temporal lobe was practically entirely removed, with the exception of a small fragment of the hippocampal lobule entirely detached from the rest (Fig. 32). In

Fig. 32.

effecting the lesion the left optic tract was disorganised, and slight damage was also inflicted on the crus cerebri, so that the animal became completely hemiopic towards the right, which condition continued till death. There was also slight hemiplegia with hemianæsthesia on the right side, which, however, completely passed off in the course of a fortnight. The second lesion was established a month after the first. The removal, however, was not so complete, and it will be seen that the surface of the hippocampal lobule immediately adjoining the crus is still intact, though it is almost entirely undermined. The olfactory tracts were absolutely normal, as well as all the other cranial nerves and the rest of the brain. The animal was allowed to survive for three months, at the end of which time it was killed with chloroform. The cut surfaces of the temporal lobes were found firmly adherent to the middle fossæ of the skull, and the meshes of the adhesions were infiltrated with fluid; otherwise all had a normal appearance. The symptoms observable in this animal are of considerable interest.

Within a week after the establishment of the first lesion numerous observations were made in regard to the sense of smell and taste, which resulted in demonstrating that these were at least good. It was impossible to ascertain definitely whether there was any unilateral impairment, but they were as a whole keen enough to enable the animal to avoid and discard substances formerly distasteful to it. Thus, it refused to eat pieces of apple smeared with aloes, smelling them and at once throwing them down. A piece of apple sprinkled with sulphate of magnesia it

examined carefully by smell, and, after tasting a mouthful, threw it away. It, however, eagerly devoured a piece which had not been in any way drugged. Similarly it refused to eat apple sprinkled with sulphate of zinc, and would not touch a piece smeared with colocynth. Such and similar observations were frequently made and confirmed, and there was no doubt whatever that it enjoyed excellent olfactory and gustatory sensibility.

On the day after the second operation, and for two days subsequently, the animal was in good physical health and strength, though somewhat dull, appeared to have lost all inclination to eat spontaneously, but it devoured greedily whatever was offered it, and showed no signs of disgust when pieces of food were given it copiously sprinkled with aloes; nor did it make any grimace when a pinch of aloes was placed in its mouth, but continued eating unconcernedly. On the fifth day after the operation the condition was still the same. On this day, while picking up its food from the floor of the cage, it not infrequently filled its mouth with sawdust, of the nature of which it did not seem to be aware. On the sixth, seventh, and eighth days similar tests were repeated with precisely the same results. There was no expression of disgust when the food offered it was copiously sprinkled with aloes, colocynth, or quinine. On the eleventh day a pinch of colocynth placed in its mouth caused no sign of distaste; the same placed in the mouth of its companion monkey caused violent nausea. On the eighteenth day the animal, which was very tame, would lick one's fingers which had been dipped in powdered aloes, and it drank up a dish of milk mixed with the same substance which its companions would not touch. A third animal which was offered the dish took a sip, and then, after a doubtful look, smacked its lips suspiciously, and would not take any more. In order to associate the disagreeable taste of aloes with a very definite and strong smell, I had some powdered aloes mixed with musk, so that there should be no doubt whatever as to the odoriferous character of the objectionable substance. This, however, made no difference. Pieces of food smeared with musk-aloes were eaten quite as readily as others; it seemed to have no suspicion of tricks played upon it, for it would come and lick musk-aloes off the blade of a knife as if it had been something nice. Its companion, however, looked askance and kept at a safe distance after having once experienced the result. At the end of a month the animal, which was in perfect health and full of fun and romps, continued unconcernedly to eat raisins smeared with musk-aloes, which its companion threw down at once as soon as it smelt them. Six weeks after the operation, a pinch of aloes was placed in its mouth. It seemed quite indifferent, and exhibited no signs of disgust. The same placed in the mouth of its companion caused retching, salivation, and comic attempts to rub the offending substance from its lips and tongue. Another animal which had not been tested in this way before vomited profusely several times, but our experimental animal within a few minutes afterwards did not refuse to lick some of the same powder off the blade of a knife. Two months after the operation it still did not refuse to lick a finger smeared with musk-aloes, and ate several pieces of apple smeared with the same, which none of the other animals, three in number, would have anything to do with. It also licked up a quantity of sugar, which was copiously mixed with aloes. The quantity of the drug it ate not unfrequently produced the usual medicinal effect. For nearly three months after the operation, the monkey continued almost entirely indifferent to substances, the smell and taste of which were such as to cause the other monkeys to avoid them, and made no grimaces when they were placed in its mouth. But it began at this time to show indications that it did not relish them, as it not unfrequently dropped pieces of apple and other morsels of food which were sprinkled as before. It occasionally sniffed at what was offered it before proceeding to eat, and would throw it down without tasting. But whether this was due to any sense of smell or merely an habitual action was not quite clear, for it would throw down shells of nuts, crusts of bread, and husks, which are practically without smell, after examining them. It also exhibited likes and dislikes in the matter of food, as, for instance, preferring apples to boiled potatoes, and it seemed to like sugar and boiled rice; but whether these likes and dislikes depended upon purely sapid characters I could not positively determine. The general results, however, of my observations incline me to believe that the animal's faculties of smell and taste, though obviously impaired, were not entirely abolished. It, however, for a considerable time after

¹⁹ Figs. 1b, 3a, 6c., *op. cit.*

bilateral destruction of the lower extremity of the temporal lobe, did not refuse to eat substances the smell and taste of which are in the highest degree objectionable to normal animals, and I do not think it is possible to explain this otherwise than on the hypothesis that the centres of olfactory and gustatory perception were, if not completely, at least extensively disorganised. It would have been well to have carried out further observations on this point, but—owing to the rather excessive mortality among my monkeys occurring at the time of the influenza epidemic—I have not been able as yet to extend my researches in this direction.

An interesting accidental experiment on a dog has been recorded by Munk which is of importance in reference to the question before us. Munk observed that a dog which he had rendered blind by bilateral destruction of its visual centres seemed unable to discover by the sense of smell pieces of meat which were scattered before it. A slight sniffing which it occasionally made was the only indication that it might possess some traces of olfactory sensibility. The animal continued in this condition for several months, at the end of which time it was killed. It was found after death that the whole of the hippocampal gyrus on each side was converted into a thin walled transparent cyst, full of fluid. Except for the cicatrices caused by the removal of the occipital lobes, the brain was otherwise normal, as well as the olfactory tracts and bulbs. Though Munk is of opinion that this case shows that the hippocampal gyrus is the centre of smell, yet inasmuch as the hippocampal lobules were implicated as well as the rest of the hippocampal gyri, we may regard it as merely a confirmation of the facts which indicate that the sense of smell is localised more particularly in the hippocampal lobule.

Luciani,²⁰ as the result of his experiments on dogs, concludes that: "No evident deficiency of smell follows extirpation of the temporal lobe; but if the lesion extend to the neighbouring convolution above the fissure of Sylvius, one observes a notable diminution of that sense. Finally, a number of experiments show that an extensive decortication of the gyrus hippocampi, as well as partial ablation of the cornu ammonis, produces olfactory disorders, at first an almost complete loss of smell—a fact which seems to indicate to us that this portion of the brain is the central point of the olfactory sphere."

Luciani is also of opinion that each centre is in relation with both nostrils, but more particularly with the nostril on the same side. In the diagram, however, which he gives of the limits of the olfactory sphere, he extends it upwards into the parietal region as far as the longitudinal fissure, and partly, also, towards the frontal lobe. In regard to the sense of taste, he states that on one occasion, in a dog, he found that, after unilateral extirpation of the fourth external convolution, and of a portion of the gyrus hippocampi, the animal seemed to be less sensitive to bitters (digitaline) on the opposite side of the tongue. (This is misstated in *Brain*. A reference to the original experiment²¹ shows that the lesion was in the left hemisphere; smell was lost in the left nostril, and taste on the right side of the tongue.)

Clinical and pathological evidence in favour of the localisation of the senses of smell and taste is as yet comparatively scanty. We have seen that, from anatomical considerations at least, the olfactory centre is in direct relationship with the nostril, but I have already mentioned that the symptoms of hysterical hemianæsthesia would appear to indicate that the olfactory, like the other centres of special sense, are in relation with the opposite side. It is questionable whether the coincident general anæsthesia of the nostril met with in this condition altogether explains the anosmia; for I have found that smell is not abolished when the general sensibility of the nostril is lost in consequence of disease of the fifth nerve. It is, however, difficult, with our present knowledge, to trace an anatomical connection between the nostril and the opposite side of the brain. The matter is, therefore, one which requires further investigation. There are clinical cases which plead in favour of the direct relationship of the olfactory centres. It may be objected against those reported by Ogle, Fletcher and Ransome,²² in which anosmia was found associated with aphasia and right hemiplegia, that there may have been direct implication of the olfactory tract or bulb. But a case has been reported by Churton and Griffith,²³ in which smell was impaired on the same side as the lesion, namely, a tumour which

caused erosion of the uncinate convolution, and which did not appear to have, directly at least, affected the olfactory tract.

Several cases have been recorded of olfactory auræ or crude sensations of smell, in association with lesions implicating the region of the uncinate gyrus. One has been reported by McLane Hamilton,²⁴ without any implication of the olfactory nerves. Another has been recorded by Worcester,²⁵ and a third by Hughlings Jackson and Beever,²⁶ in which the whole of the anterior end of the right temporo-sphenoidal lobe was the seat of a tumour involving the nucleus amygdalæ and the medullary fibres. Smell, however, was not lost in this case, either on the one side or on the other, which can be accounted for by the fact that the whole of the centre was not destroyed by the tumour.

This case as well as the others noted are, as Dr. Jackson remarks, of considerable value in determining sensory localisation, though naturally they do not afford such precise indications as to the position and limits of the centre as are afforded by destructive lesions causing entire abolition or considerable impairment. So far as they go, however, they harmonise with the results both of anatomical and physiological investigation. The smacking of the lips and tasting movements which are sometimes observed along with crude sensations of smell—"the dreamy states" of epileptic attacks—are probably discharges of the gustatory centres; but we have still fewer pathological facts bearing upon this point than on the situation of the olfactory centres. A case has been related by Dr. James Anderson²⁷ of a peculiar smell and taste sensation and dreamy state associated with tumour affecting the left temporo-sphenoidal lobe; but the lesion was too extensive and too indefinite to allow of any precise conclusions being founded on it as to the position of the gustatory centre.

THREE CASES OF ANTHRAX TREATED SUCCESSFULLY BY THE HYPODERMIC INJECTION OF MERCURIC PERCHLORIDE.

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DURING the summer of last year there were rumours of the occurrence of several cases of malignant pustule at a small village in the neighbourhood of Teheran, and several deaths were stated to have taken place among those affected; there was also a great mortality among the sheep of the district, said to be from the same cause. One day an old man was brought to me from the village in question, with undoubted anthrax of nine days' duration, on the lower lip, which was swollen, hard, of a deep red colour, and with a small crack, the edges of which were blackened, from which a thick sticky serum oozed sluggishly. He was in an extremely exhausted condition, with short, laboured respiration, varying from 50 to 60 per minute; the face was puffy and discoloured, pulse 140, and temperature 104°. The cedematous swelling was so extensive, and the patient's condition so critical, that I hesitated to excise the pustule, and contented myself with applying lint steeped in a solution (1 to 1,000) of mercuric perchloride to the sore, and at the same time injected, at four different points, two drachms of the same solution into the swollen and brawny tissue, which extended to below the clavicle and the point of the shoulder. The old man was so much exhausted that I kept him on the Legation premises till the following day, when to my great surprise I found the respirations almost normal, pulse 110, and the temperature 100°. I repeated the injection to the extent of one drachm of the solution, and the man returned home on an ass. After two days he returned, having walked in from the village, some five miles, much improved in every respect. The swelling was now limited to about an inch round the pustule, the edges of which had lost their black discoloration. I repeated the injection of one drachm. No further applications were necessary, and after ten days the cure was complete.

The man confirmed the story of the outbreak in the village, and stated that there had been six or seven deaths.

²⁰ "Sensorial Localisations in the Cortex Cerebri," *Brain*, 1885.

²¹ *Die Functions-Localisation auf der Grosshirnrinde*, p. 117.

²² See *Functions of the Brain*, 2nd Edition, p. 321.

²³ *JOURNAL*, May 28th, 1887.

²⁴ *New York Med. Journ.*, vol. xxxiv.

²⁵ *Amer. Journ. of Insanity*, July, 1887.

²⁶ *Brain*, October, 1889.

²⁷ *Brain*, vol. ix, 1887, p. 385.