V. "Experimental Degenerations following Unilateral Lesions of the Cortex Cerebri in the Bonnet Monkey (*Macacus Sinicus*)." By E. LINDON MELLUS, M.D. Communicated by Professor V. HORSLEY, F.R.S. Received May 1, 1895.

(From the Pathological Laboratory of University College, London.)

(Abstract.)

The object of this investigation was to trace by the so-called anatomical method the degeneration resulting from minute lesions of the motor area of the cortex cerebri through the brain and spinal cord, to locate the path of the conducting fibres in the internal capsule and elsewhere, to follow them as far as possible to their destinations, and by such control observations to check off the results obtained by previous excitation experiments.

Method Pursued.

The animal selected for these experiments was the bonnet monkey (*Macacus Sinicus*), and the lesions were made in the motor area of the left hemisphere. The records are here presented of degenerations resulting from fourteen (14) successful operations, three being lesions of the hallux centre, four of the thumb centre, and seven of four separate centres in the facial area. The animal being etherised the skull was opened under strict aseptic precautions, and the centre to be removed located by stimulation with a weak faradic current. A small portion of the cortex (generally about 16 sq. mm.) embracing this centre was then excised, care being taken to remove with it a portion of the underlying corona radiata, thus ensuring the removal of all the cortical cells. The scalp wound was closed with horse-hair sutures and covered with borated cotton held in position by collodion. The wound in every case healed by first intention and but slight and transient paresis resulted. The animals were killed in from 10 to 35 days after the operation, the brains and cords hardened in Müller's fluid and stained by the Marchi method.

Degeneration following the Hallux Lesions.

The portion of the cortex removed in these cases was taken as nearly as possible from the centre of the triangular space at the upper extremity of the ascending frontal convolution formed by the longitudinal fissure and the fissure of Rolando, and extending down the convolution to the posterior extremity of the superior frontal sulcus.

Numerous degenerated association fibres, both coarse and fine, were found passing to the central convolutions down to the level of the

inferior genu of the fissure of Rolando; fine fibres only passed to the superior parietal lobule; degenerate fibres, mostly fine, were traced to the posterior portion of the superior frontal convolution; both coarse and fine to the lobulus paracentralis; fine only to the precuneus, and a very little fine degeneration to the gyrus fornicatus. The degenerate fibres crossing in the corpus callosum were very fine and occupied the middle third of its antero-posterior extent. This corresponded very closely with the antero-posterior extent of the ascending parietal convolution at this level. Degenerate fibres could be traced into the convolutions of the right hemisphere corresponding to the distribution of the degeneration in the left, but considerably less in amount, and the area of distribution being rather less extensive. Both coarse and fine degenerate fibres, varying considerably in amount in different animals, pass from the lesion through the mesial half of the centrum semiovale to the left internal capsule, in the lower levels of which they are located in the middle third of the posterior limb. From the internal capsule most of the fine degeneration passes into the optic thalamus. In the left crus the degeneration is very evenly scattered over the middle third, and many coarse degenerate fibres pass from here into the substantia nigra. At the decussation of the pyramids the tract divides, the larger portion crossing to the opposite lateral column while the smaller goes to that of the same side (*vide* Preliminary Report*). The amount of degeneration passing to the lateral column of the same (left) side varies from a third of all the degeneration in one case to about a twentieth in the other two. In each case a small number of degenerate fibres remain in the left anterior column after the completion of the decussation. The amount varies in different cases and is not apparently dependent on the proportion of degenerate fibres passing to the lateral column of the same side. The relations and extent of the degenerated areas remain unchanged throughout the cervical and dorsal cord. The degeneration in the crossed tract of each side is evenly scattered over its entire area, the two sides only differing in the density of the degeneration.

In the upper cervical region the tendency of the crossed tract to mingle with or encroach on the boundaries of the direct cerebellar tract is well illustrated. In the lumbar region the degeneration in each crossed tract and in the left anterior column (Tooth) begins to go out, and in the only case examined at that level the degeneration had not all disappeared at the level of the third sacral root.

Degeneration following Lesions of the Thumb Centre.

The portion of cortex removed in these cases was from the ascending parietal convolution between the lower extremity of the

* 'Roy. Soc. Proc.,' 1894.

intra-parietal sulcus and the fissure of Rolando, and a little above the inferior genu of the fissure of Rolando (Beevor and Horsley). In these cases the majority of the degenerated association fibres pass to the ascending frontal and ascending parietal convolutions, rather more to the latter than to the former. In these lesions of the thumb centre degenerate fibres were distributed to these two convolutions from the border of the longitudinal fissure nearly to the fissure of Sylvius, the fibres passing upward from the lesion being coarse, while those passing downward were fine. Fine degeneration was traced into the posterior portion of the middle and inferior frontal convolutions, and in one case to the supra marginal and angular gyri. In two cases it was also found passing to the upper or posterior portion of the superior temporal convolution. In various instances a few degenerate fibres passed to the precuneus and lobus quadratus and paracentralis and to the gyrus fornicatus.

There is considerable variation in the size of the fibres crossing in the corpus callosum after lesion of the thumb centre. With slight variations it was situated in the middle third. The distribution of the degenerate fibres to the convolutions of the right hemisphere corresponds very closely to that in the left, though less in amount and slightly less in area. The same arrangement of the coarse and fine fibres observed on the left side prevails on the right—coarse above the lesion, fine below. The degeneration passing from the lesion downward through the centrum semiovale is both coarse and fine. These fibres are more scattered and the area of degeneration is greater than that in lesions of the hallux centre, both laterally and antero-posteriorly. In one case only was there any apparent separation of the coarse and fine fibres in the centrum semiovale, and there the coarser fibres were anterior to the fine. The same arrangement prevails in the internal capsule, the coarser fibres representing the pyramidal fibres being found (in the lower levels) in the middle third of the posterior limb, while the fine fibres, mostly representing the corona radiata thalami, are largely situated in the posterior third of the posterior limb. Between the upper and lower levels of the capsule there is a movement of the degeneration forward, and in the lower levels most of the fine degeneration has already passed into the thalamus. In one case a little fine degeneration was found in the right internal capsule occupying a position corresponding to that of the fine degeneration in the left capsule. This all passed into the right thalamus. In another case both coarse and fine degenerate fibres were found in the right capsule occupying the same position and pursuing the same course as the corresponding fibres on the left side. These fibres come from the area of degeneration in the right centrum semiovale, into which the fibres crossing in the corpus callosum could be traced, but no continuous fibres could

be traced from the corpus callosum into the right internal capsule. The coarse degeneration, mixed with more or less fine, is found in the middle third of the crus. In each case some fine degeneration reaches the crus, where it invariably takes its position external to the coarse fibres. In the entire group a large proportion of the degeneration passes to the substantia nigra. This varies from a half to nearly the whole of the degeneration reaching the crus. The fine degeneration referred to external to the coarse disappears from the crus, but could not be traced to its destination. The coarse degeneration observed in one case in the right internal capsule reached the crus, where all but a few fibres disappeared. In one case the last remaining degenerate fibres disappeared in the upper levels of the pons. In another about half those remaining disappeared in the lower pons and upper medulla, but could not be traced after leaving the pyramidal tract. In one case only was there a division of the degenerated tract at the decussation of the pyramids, such as was observed in lesions of the hallux centre, and the amount of degeneration passing to the left lateral column was less than in either of the hallux cases. This was also the only case in which a few degenerate fibres remained in the left anterior column after the completion of the decussation. In one of the remaining cases the few degenerate fibres remaining in the left anterior column cross to the right lateral column, and in the other the degeneration in each pyramid apparently goes to the crossed tract of the opposite side. In each of the three cases in which the degeneration reaches the cervical cord, its amount and relations remain unchanged in the upper and middle cervical regions. From the level of the seventh cervical root downward the degenerate fibres steadily and gradually disappear, and at the level of the third dorsal root there are none left, thus confirming the results obtained by excitation of the nerve roots (Ferrier and Yeo, Forgue, &c.).

Degeneration following Lesions of the Facial Area.

Seven successful experiments were performed to determine if possible the degeneration resulting from minute lesions within the facial area. In four of these the lesion was practically the same, the portion of cortex removed being just above the fissure of Sylvius and just anterior to the plane of the fissure of Rolando, representing the movement of opening the mouth straight; in one the lesion was in the same level, and just posterior to the fissure of Rolando, and the movement elicited on stimulation was pursing the mouth towards the opposite side; in one the lesion was just above the fissure of Sylvius and anterior to the plane of the sulcus transversalis frontalis inferior, and the movement represented was the

rhythmical movement of mastication. In the other experiment the portion of cortex removed was in the level of the inferior genu of the fissure of Rolando, between the fissure of Rolando and the precentral sulcus, and the movement obtained on stimulation was elevation of the opposite angle of the mouth. None of the brains in this group were examined above the level of the inferior genu of the fissure of Rolando. In three cases, one of lesion of the mastication centre and two of lesion of the centre for opening the mouth, only fine degeneration resulted from the lesion; in the other four both coarse and fine. In two cases of "opening mouth" and in the lesion posterior to the plane of the fissure of Rolando, coarse degenerate association fibres were only found in the upper levels of the lesion or above, where they were mixed with more or less fine, the proportion of coarse to fine increasing from the lesion upward, while the aggregate amount of degeneration decreased. In all the lesions on the border of the fissure of Sylvius anterior to the fissure of Rolando, most of the degeneration was found in the ascending frontal convolution from the border of the fissure of Sylvius to the level of the inferior genu of the fissure of Rolando. In the lesion of the mastication centre all the degeneration was very fine, and in the left hemisphere, with the exception of a few fibres near the base in the ascending parietal, the degenerate association fibres were confined to the ascending frontal convolution. In the four lesions of the centre for opening the mouth degenerate association fibres were also distributed to the ascending parietal, the posterior half of the inferior frontal, and the posterior or upper extremity of the superior temporal convolutions. In only one of these four cases was any degeneration found in the inferior temporal convolution. In the lesion posterior to the plane of the fissure of Rolando both coarse and fine degeneration was distributed to the central convolutions, the fine degeneration above the lesion being mixed (as noted above) with coarse fibres, which were more numerous in the ascending parietal convolution. No degeneration was traced into the frontal convolutions in this case, but a good deal of coarse degeneration passed from the superior temporal convolution to the posterior extremity of the internal capsule, where it turned downward and forward in the posterior limb. A mingling of this with the degeneration in the internal capsule coming from the lesion could not be demonstrated. In the case of the lesion on the upper border of the facial area the coarse degenerated association fibres are almost entirely confined to the neighbourhood of the lesion. In addition to this, fine degeneration is distributed to the central convolutions nearly to the fissure of Sylvius. The degeneration in the supra-marginal gyrus and in the inferior frontal convolution is much more than in any other experiment, the degeneration in the latter convolution reaching to the anterior extremity of the precentral

sulcus. No degeneration in this case was found in the temporal lobe. In all directions the amount of degeneration decreased as the distance from the lesion increased.

The size of the degenerate fibres crossing in the corpus callosum corresponded to that of the fibres proceeding from the lesion, *i.e.*, in each case in which both coarse and fine fibres were found proceeding from the lesion both coarse and fine fibres crossed in the corpus callosum. The coarse fibres in the corpus callosum were finer than the coarse fibres elsewhere, and much less numerous than the fine fibres. In all the lesions anterior to the plane of the fissure of Rolando the degeneration was in the posterior two-thirds of the anterior half of the corpus callosum. Following the one lesion posterior to the plane of the fissure of Rolando it was in the middle third, thus corresponding to the hallux and thumb lesions. The convolutions of the right hemisphere were examined in four cases, and, with the exception of the case of the lesion of the mastication centre, the degeneration, while corresponding to that on the left side, was rather less extensive and less in amount. The majority of the degeneration was in all cases distributed to the central convolutions. In the case of the lesion of the mastication centre the degeneration was even more extensive and of about equal amount on the right side. In most of these cases but little of the degeneration passing from the lesion to the left internal capsule appears in the centrum semiovale as it reaches the capsule by passing over and around the anterior angle of the putamen at a lower level. As much of this as reaches the centrum semiovale, together with the fibres going to the corpus callosum, occupies a more extensive area than in either the hallux or thumb lesions, corresponding to the antero-posterior extent of both central convolutions. The angle of the mouth centre was the only case in which both coarse and fine fibres degenerated from the lesion in which there was not marked grouping of the coarse fibres anterior to the fine.

In all the lesions of the facial area the degenerations in the uppermost levels of the capsule, *i.e.*, the coarser fibres which pass down *through* the capsule, are situated in its anterior portion, and in the lower levels move backward till they occupy in the lower levels the middle third of the posterior limb. Between the upper and lower levels of the capsule most of the fine degeneration passes from the posterior limb into the thalamus. In the lesion of the mastication centre, though the degeneration in the capsule is all fine, but little passes to the thalamus. In the three cases referred to in which there were only fine degenerate fibres, a varying amount of fine degeneration was observed in the posterior limb of the right internal capsule corresponding in position to that in the left. In one opening of the mouth lesion the amount on the right side was nearly

half as much as on the left, in another it was nearly equal on the two sides, and in the lesion of the mastication centre there was quite as much on the right as on the left side. In the other four lesions of the facial area there was no degeneration observed in the right internal capsule. In the lesion of the centre for the angle of the mouth degenerate fibres were observed in the striations of the right thalamus, some of them being pretty coarse. In two cases fine degeneration was observed crossing in the posterior commissure. In the three cases in which fine degeneration only resulted from the lesion, most of this disappears before reaching the crus. In the lesion of the mastication centre it could not be traced, but in the other two it passed to the thalamus from both left and right capsule. In all three a small amount of fine degeneration was found in the middle third of both crura. In one case this passed to the substantia nigra, but in the other two it could not be traced. In the other four lesions of the facial area the coarse degeneration from the left internal capsule was scattered very evenly over the middle third of the crus encroaching a little upon the lateral third. Some of the fibres passed into the substantia nigra or the sub-thalamic region, and in one case a considerable number to the anterior corpus quadrigeminum. The remaining degenerate fibres begin to leave the left pyramid at the junction of the pons and medulla, passing as single degenerate fibres to the facial nucleus of one or the other side. Below the level of the facial nuclei these fibres pass to the motor nuclei of the glosso-pharyngeus and the vagus on both sides, the majority crossing the raphe to reach the nucleus on the opposite side. Occasional fibres were observed, which apparently passed to some termination dorsal to these nuclei. This movement of degenerate fibres continued as far as the sensory decussation. A few degenerate fibres (probably thumb or finger fibres) remained in the pyramid, and crossed in the decussation to the right lateral column, and disappeared in the lower cervical or upper dorsal region. No degenerate fibres remained in the left anterior column after the decussation, and there was no apparent division of the tract, as in hallux and thumb lesions.

Under the head of "other appearances resembling degeneration" are recorded appearances which are of doubtful significance, but yet so closely resemble degeneration that they are well calculated to deceive and lead one into grave error. Among these may be mentioned apparent degeneration in the left lateral geniculate body and optic radiation, in the posterior longitudinal fasciculi, the roots of all the motor cranial nerves of both sides and the corpus trapezoides (Marchi), and in one case extensive degeneration in the optic tract. The degenerations in the roots of the motor cranial nerves and in the corpus trapezoides could hardly have been due to the lesions, as

exactly the same appearances were found in the brains of control animals in which there was no lesion.

In the general summary attention is called to the fact that the distribution of the degenerate association fibres in the thumb lesions corresponded with the measurements made by Bevan Lewis of the corpuscles of the fourth layer of the cortex in this region, *i.e.*, that coarse fibres were distributed to the upper part of the motor area and fine fibres to the lower part. In four of the experiments (one thumb and three facial) neither pyramidal fibres nor fibres connecting the nuclei of the cranial nerves directly with the cortex were found to have degenerated. Yet in each of these cases the characteristic movement was obtained from stimulation of the area removed quite as readily as in any other case. The degenerate fibres passing through the internal capsule in these cases apparently belong to two distinct systems, which are also more or less represented in the other experiments. One of these, composed almost entirely of fine fibres, passes from the posterior limb of the internal capsule into the outer surface of the optic thalamus, and represents the corona radiata thalami. These fibres are to some extent mixed with the pyramidal fibres in the posterior limb of the internal capsule, but are mostly situated in the posterior third, and, as they pass from there into the thalamus, make room for the entrance of the sensory (non-excitable) tract. The other of the two systems referred to, largely composed of coarser fibres, passes through the internal capsule into the crus, and apparently ends in the substantia nigra. These fibres are of much the same calibre, and apparently occupy the same position in the internal capsule and crus as the true pyramidal fibres. Both these tracts appear to arise in all portions of the motor cortex coming within the range of these experiments. All the degenerated pyramidal fibres from the hallux and thumb lesions were found to enter the capsule at or near the posterior extremity, while the corresponding fibres from the facial lesions entered the capsule at or near the anterior extremity, and the former were displaced forward and the latter backward until in the lower levels of the capsule they all found a place in the middle third of the posterior limb. It is also shown that a line can be drawn from the fissure of Sylvius upward, so dividing the motor area into two parts, that all the facial lesions from which fibres enter the anterior portion of the capsule would be in the anterior division, and all the hallux and thumb lesions from which fibres enter the posterior portion of the capsule would be in the posterior division. In the movement of the facial fibres backward between the upper and lower levels of the capsule they would necessarily, at some level, envelop the genu, which would account for the fact that they have always been described as occupying that position. The location of these degenerations in the internal capsule

corresponds very closely with the results of excitation of the fibres in the living animal of the same species (Beevor and Horsley). In all the cases in which there was coarse degeneration in the internal capsule it was, with two exceptions (both hallux cases) grouped on the outer edge of the capsule. Attention is called to the fact that a large proportion of the coarser fibres passing down through the capsule enter the substantia nigra, and these experiments show this tract to be nearly or quite as large as that passing down into the pyramid. These are apparently fibres which have been looked upon as pyramidal, and, as the "pyramidal tract" has been shown to be even more extensive in the medulla and below the decussation than in the internal capsule, it follows that the fibres passing to the substantia nigra are probably replaced by others arising at lower levels. These degenerations show that in the monkey the facial fibres are situated in the middle third of the crus, in which they are mingled with the fibres of the pyramid, and that they do not occupy a space by themselves mesial to the pyramid.

VI. "On the Cause of the Differences in Lichtenberg's Dust-Figures: Preliminary Note." By SILVANUS P. THOMPSON, D.Sc., F.R.S. Received May 9, 1895.

As ordinarily produced by dusting a mixture of red-lead and lycopodium upon a surface which has been charged by contact with the knob of a Leyden jar, the dust-figures present a remarkable and hitherto unexplained difference of form. The positive figures consist of white lines branching in stellate or dendritic patterns, whilst the negative figures exhibit red patches of circular or ovate outline. The differences, save in the matter of colour, are not due to the powders used nor to the nature of the dielectric surface chosen for the experiment. They vary only slightly with the nature of the gas; but are more considerably altered by the rarefaction of the air. The author found that the dendritic patterns of the positive figures are correlated to the brush form of discharge, whilst the rounded patches of the negative figures are due to the silent discharge of electrified winds. When polished metal surfaces are used in air for producing the discharges (as in the usual case when the knob of a Leyden jar is employed), negative electrification more readily discharges itself in a wind, positive electrification less readily, disruptively, as a brush. But where a smooth surface of a peroxide, such as the peroxide of lead, is substituted for a metal knob, positive electrification will discharge itself as a wind, giving rise to white positive figures of rounded outline; while negative electrification will under certain conditions produce a brush discharge from the peroxide surface,