

DEGENERATIONS IN HEMIPLEGIA: WITH SPECIAL REFERENCE TO A VENTRO- LATERAL PYRAMIDAL TRACT, THE ACCES- SORY FILLET AND PICK'S BUNDLE.

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IN this paper I propose to describe and discuss certain tracts of fibres which are frequently seen degenerated in the human subject in association with the pyramid in cases of hemiplegia. These tracts include:—(1) A ventro-lateral pyramidal tract; (2) The accessory fillet; (3) Pick's bundle.

My best thanks are due to the Medical Staff of the National Hospital for permission to make use of their cases, and to Professor Victor Horsley and Dr. James Collier for valuable suggestions and criticisms. For the microphotographs I am also indebted to Mr. Horsley.

METHOD.

IN each case the whole central nervous system has been first hardened in formalin; the brain for seven days in a 20 per cent. solution, the cord for three days in a 10 per cent. solution. They were then cut into blocks of a convenient size and stained in Busch's fluid (an aqueous solution of osmic acid and sodium iodate) until well penetrated; serial sections were then cut in celloidin and mounted in balsam. Some sections, however, were counter-stained before mounting by Robertson's method in order to demonstrate more clearly the general undegenerated structure.

Sections were stained of all regions from the crura cerebri to the coccygeal region; in one case sections were made through the internal capsule, corona radiata and part of the cerebral cortex.

In this way it was possible to trace the degenerations from their point of origin to their regions of distribution.

It will thus be seen that a modified Marchi method was alone relied upon to determine the degeneration.

Case 1.—Clinical history. Andrew H., aged 52, was admitted into the National Hospital, under Dr. James Taylor, on December 4, 1900, thirty-seven days after the sudden onset of right hemiplegia and aphasia in association with old rheumatic endocarditis. There was complete paralysis of the arm and leg, partial paralysis (of the supranuclear type) of the right side of the face, the paralysis being equally marked in voluntary, emotional and associated movements: there was complete motor aphasia and much mental disturbance. The nervous condition remained unaltered until his death, on January 7, 1901, from heart failure.

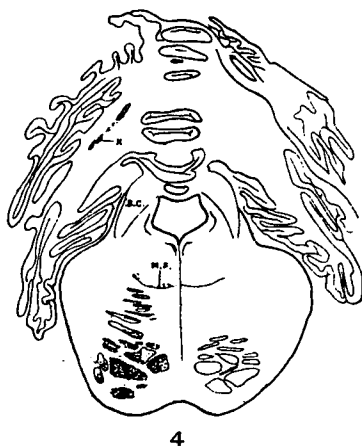
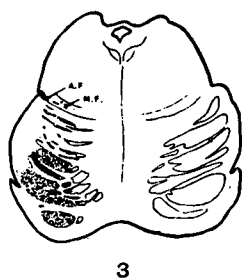
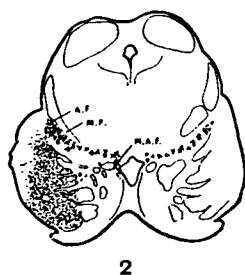
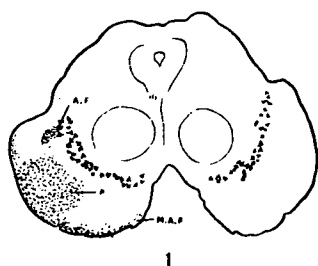
Autopsy.—The mitral valve was found to be almost blocked by large vegetations covered with laminated clot; there were several recent infarcts of the left kidney and the spleen.

There appeared to have been blocking of one of the main branches of the left middle cerebral artery in the Sylvian fissure. The resulting softened area seen on the surface of the cortex was small and included only Broca's area, a small piece of the anterior end of the upper temporal convolution and the lower end of the ascending frontal convolution; the whole of the island of Reil appeared to be softened. Coronal sections through the centre of the insula showed that the lesion involved the deeper structures down to the optic thalamus, the upper and outer edge of which was alone softened, the red nucleus being intact. The lenticular and caudate nuclei were largely softened, but the internal capsule only partly involved with the original lesion, the frontal and temporal fibres of the capsule escaping injury; the whole of the fibres from the Rolandic area were interrupted in this region.

DEGENERATIONS.—Coronal sections of the left cerebrum through the island of Reil confirmed the extent of the degeneration as inferred from macroscopic examination, only the upper one-fourth of the optic thalamus (exclusive of the red nucleus) being involved. Consequent upon this lesion there was extensive degeneration in the left crus cerebri, but none in the right crus, nor in the tegmental region of either side. The pyramidal fibres in the middle region of the crura were all degenerated; the inner two-fifths (the fronto-pontine region) and the outer one-sixth (the temporo-pontine region) of the longitudinal fibres were in the main free from disease, but the distinction between degenerated and undegenerated regions was not sharp, the two sets of fibres intermingling at the junction. One small degenerated bundle, somewhat less than one-twelfth the size of the pyramid in this region, and lying immediately dorso-lateral to the latter, gradually becomes more dorsal and lateral, until at the level of the posterior corpus quadrigeminum (case 1, fig. 2) its fibres mingle with the outermost cells of the substantia nigra, and the degenerated tract lies close up against the fillet. Lower sections show that this tract spreads itself out in the uppermost part of the pons, and that its fibres come to lie in small groups in the middle fillet itself (case 1, fig. 3). At first they occupy the outer part of the fillet on its ventral aspect, but they quickly pass further towards the middle line and gradually assume a more dorsal aspect, many of them leaving the fillet and being distributed to the tegmentum as single fibres. It was impossible to trace individual fibres to the nuclei, but in the main they appeared to end in the region of the motor nucleus of the trigeminus and the facial nucleus of the same side; a few fibres crossed the middle line and were distributed to the corresponding nuclei of the opposite side. No degenerated fibres were visible in the tegmentum of the lower part of the pons below the level of the facial nucleus, nor could any be seen in the inter-olivary region of the medulla.

Through the upper part of the pons certain reinforcements to this tract—the “accessory fillet”—take place

CASE 1.



The accessory fillet (*A. F.*) and mesial accessory fillet (*M. A. F.*) separate from the pyramid in 1, and pass to the middle fillet (*M. F.*) in 3. In 5 accessory fillet fibres pass to the motor nucleus of trigeminus (*N. Mot. V.*) *X* represents the bundle described on p. 471.

from other degenerated fibres lying in the most dorsal part of the crusta. It will be seen from the diagram (case 1, fig. 3) that in the uppermost regions of the pons, where the pyramidal and other longitudinal fibres are beginning to be cut up into larger or smaller bundles by the transverse fibres, that certain of the bundles lying nearest to the tegmentum are narrow horizontal bands of a concavo-convex shape, lying near to and parallel with the fillet. These bands are derived from that portion of the longitudinal fibres of the crus which lie immediately outside the pyramidal fibres proper, and between them and the accessory fillet. These bundles, as seen in the upper pontine region, contain many degenerated fibres, but none of them are as heavily degenerated as are the larger pyramidal bundles situated more ventrally, although they show more degeneration proportionately to the number of healthy fibres than does the middle fillet. It is from these bundles that fibre accessions are constantly coming to the middle fillet throughout the upper pontine region as the accessory fillet becomes attenuated by sending fibres into the tegmentum. These narrow bundles of fibres are still seen as low down as the corpus trapezoides (case 1, fig. 6), between the fibres of which they lie in very thin sheets, appearing as mere lines in cross section; but below this level they have disappeared completely and the only degeneration to be seen is in the left pyramid. Other fibre accessions reach the accessory fillet from Spitzka's bundle (the mesial accessory fillet of von Bectereu). This bundle leaves the degenerate pyramid in the crus (case 1, fig. 1) and passes inwards round the fronto-pontine tract and among the innermost cells of the substantia nigra (case 1, fig. 2) to reach the mesial end of the middle fillet of the same side. The number of fibres thus supplied to the middle fillet is small—less than a quarter of the number supplied by the accessory fillet. At about the level of the decussation of the fourth nerves the two sets of fibres mingle and can no longer be distinguished.

The behaviour of the pyramid in the pons calls for some comment. When the descending fibres from the crus are

it assumes in the spinal cord, I propose for this tract to use the term "ventro-lateral pyramidal tract." In this case it could be traced as a distinct tract as far as the third cervical segment of the cord, below which the fibres become scattered, but still lie in the ventro-lateral marginal region; they could not be traced beyond the upper dorsal segments.

The pyramid, after giving off this tract, decussates with its fellow, and at the same time gives off from its left side a bundle of fibres which does not cross the middle line but curves sharply backward and at once spreads out, mingling with the undegenerated fibres of the right pyramid. These are the lateral uncrossed fibres of the pyramid.

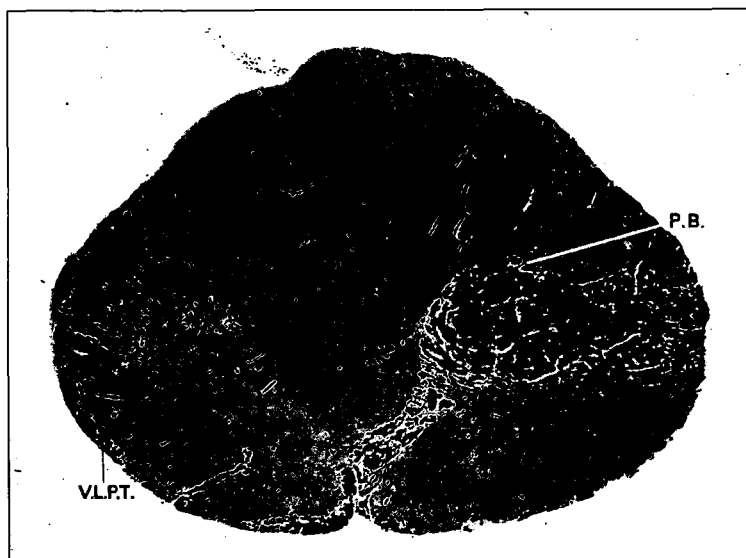
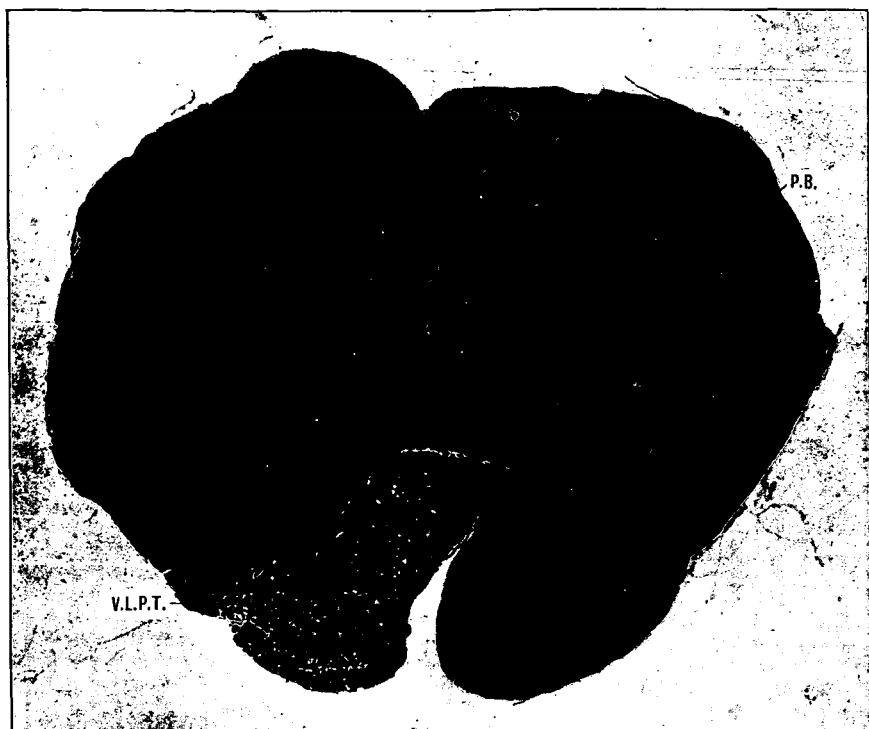
At the lower end of the decussation there is left behind an uncrossed tract about one-eighth as large as the crossed pyramid lying near the anterior fissure—the direct pyramidal tract. No fibres could be seen going to the opposite direct pyramidal region (ventral crossed bundle), nor to the opposite ventro-lateral region.

The crossed pyramid quickly assumes an equilateral triangular appearance, one side being limited by the posterior horn, a second by a slightly curved line parallel to the outer edge of the cord, and the third by a line drawn outwards and slightly ventralwards from the region of Clarke's column. The direct cerebellar tract thus separates it in the main from the edge of the cord, but many fibres are seen to lie separated from the main mass, some mixed with the fibres of the direct cerebellar tract, and more at the periphery of the cord both outside and ventral to that tract.

The crossed pyramidal tract can be traced down to the coccygeal region. The homolateral fibres can be traced down to the fifth sacral, and the direct pyramidal tract to the first lumbar segments of the cord.

Pick's bundle.—Another bundle of fibres needs description. In the lower sections of the medulla are seen degenerated four small bundles of fibres closely massed together at the inner side of the substantia gelatinosa. Traced upwards these fibres—which correspond to what is usually known as Pick's bundle—become rapidly diffused and lost in the

CASE 1.



Microphotographs of sections of medulla, showing the origin of the ventro-lateral pyramidal tract and Pick's bundle.

region of the nucleus ambiguus, not a single fibre being visible in this region at the lowest pontine level, and none of them can be seen to cross the middle line. Traced downwards towards the pyramidal decussation these fibres retain their position but increase in number and in compactness, lying close to the ventro-lateral aspect of the posterior horn at its junction with the substantia gelatinosa in the upper part of the first cervical segment. Here the degenerated bundle appears to gradually merge into the degenerated crossed pyramid which now lies immediately adjacent to it. For several sections, however, after the crossing fibres of the pyramid have reached them, the bundles remain distinct and are easily distinguished. Many of the fibres then take an oblique course and are seen as though cut almost longitudinally in transverse sections, giving the impression of fibres which are curving rather sharply at this point. It was quite impossible to trace any of the fibres to the opposite (left) side through the decussation of the pyramids, as they lose their bundle form and are no longer distinguishable from the rest of the degenerated pyramid.

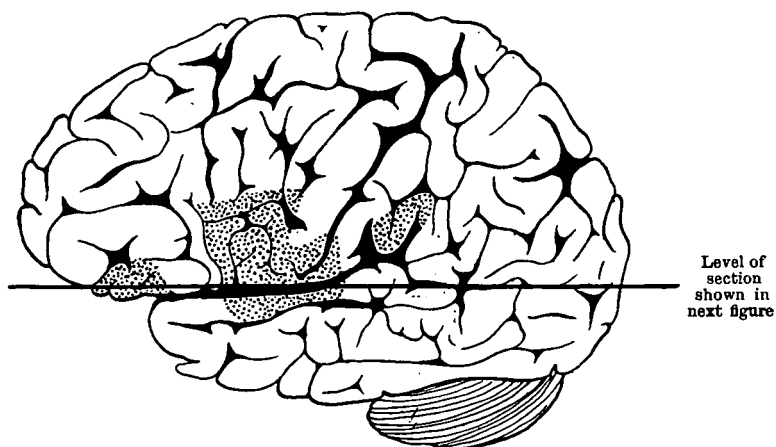
Besides the tracts already described, which all appear to have been the result of the cerebral lesion, another set of fibres having its origin in the lateral pontine region at the lowest level of exit of the fifth nerve was markedly degenerated (case 1, fig. 5). The compactness of the fibres strongly suggests that they might be nerve-roots, but their position makes such an assumption difficult to accept. There may have been a small separate focus of softening—possibly due to another embolus—but the area involved is very small and no lesion was seen: there was no downward degeneration from this point, nor could any connection with the pyramidal or other degeneration be made out, although every section was examined. The four or five heavily degenerated bundles, close together at their commencement and lying just dorso-lateral to the superior olive pass slightly upwards and rapidly curve outward and dorsalwards, diverging as they ascend in the middle peduncle of the cerebellum. A few fibres, split off from the rest, pass on the inner side of the dentate nucleus and are lost—some in

the white matter over the lateral aspect of the fourth ventricle, some in the nuclei tectis, and a few in the dentate nucleus itself. The main mass passing dorsalwards courses outside the dentate nucleus and then curves sharply to pass in a ventro-lateral direction into the peduncle of the flocculus of its own side (case 1, fig. 4). None of the fibres, except a few passing to the vermis, could be seen crossing to the opposite side and none degenerated downwards.

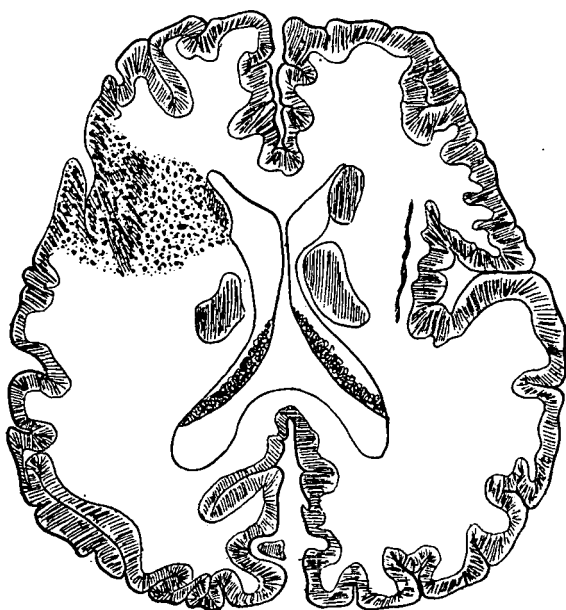
I do not know what this tract represents. Its appearance does not suggest that the fibres are merely bundles of the middle peduncle. It is possible that they are part of the direct sensory cerebellar tract of Edinger, passing from the auditory nerve to the flocculus; they certainly have no connection with the pyramidal degenerations.

Case 2.—Clinical history. Annie W. was admitted to the National Hospital, Queen Square, under Dr. Hughlings Jackson, on April 15, 1901, suffering from right hemiplegia and aphasia. She had been the subject of heart disease since infancy, and ten years before admission had suffered from epilepsy, which ceased entirely under treatment in about two years. For a year before admission attacks of œdema of legs had come on, clearing up when she lay in bed. On February 7, 1901, after being in her usual health, she woke up with inability to use the right arm or leg, and loss of speech; the leg had slowly improved, but the arm and speech remained stationary until admission. When seen on April 15 she was suffering severely from heart failure, there being evident signs of mitral stenosis, aortic regurgitation and tricuspid regurgitation; the liver was strongly pulsating. There was no hemianopia or hemianæsthesia. Motor aphasia was complete; she understood spoken words, could understand simple written sentences, could copy with the left hand, but could not write from dictation. The right pupil was larger than the left, both reacting well to light and on accommodation. The lower facial segment on the right side was almost completely paralysed—equally for voluntary and emotional movements. No difference could be detected between the power of the masseter and temporal muscles. The tongue deviated slightly to the right. There was almost complete flaccid palsy of the right arm—all movements below the elbow being completely lost—and a considerable paresis of the right leg. All the tendon-jerks were increased in the paralysed arm and leg, and the right plantar reflex was of the extensor type, the left being flexor.

CASE 2.



1.—Surface of brain: softened areas are dotted.



2.—Horizontal section of brain at level shown in figure 1.

She was kept in bed and given alcohol and digitalis, and in a few days the heart failure was largely overcome. The nervous condition, however, did not alter until May 14, when she became suddenly unconscious with stertorous breathing and slight general convulsions; she never recovered consciousness, but died next day.

AUTOPSY.—There was old disease of the mitral, aortic and tricuspid valves, and the usual associated visceral changes. The brain (case 2, fig. 1) showed areas of softening around the Sylvian fissure, involving mainly the island of Reil, the first temporal, the lower part of the ascending frontal and parts of the inferior frontal and angular convolutions. Several small branches of the Sylvian artery were occluded, but the main artery and some of its branches were patent. A horizontal section of the brain through the centre of the fissure of Sylvius (case 2, fig. 2) showed that the softening included the whole of the island of Reil and subjacent white matter down to the lateral ventricle, the head of the caudate nucleus being involved. A series of sections parallel with the first showed that the softening also included the greater part of the lenticular nucleus, but that nowhere was the optic thalamus encroached upon; this was also confirmed microscopically. The anterior limb and a few of the most anterior fibres of the posterior limb of the internal capsule were also destroyed. On the right side the middle cerebral artery was completely blocked by red gelatinous clot, and the island of Reil and neighbouring convolutions were red and slightly soft; it was evident that an embolism had occurred on this side and had been the immediate cause of death. No degeneration resulted from this lesion, which was probably not more than thirty-six hours old.

THE DEGENERATIONS.—In this case many of the *fronto-pontine* fibres were degenerated, being probably cut off from their cell-origin by the lesion in the internal capsule. Some escaped injury, so that in the upper pontine region many undegenerated fibres are seen on the inner side of the pyramid. As in case 1 the undegenerated fibres disappeared gradually and none could be seen at the level of exit of the seventh nerve.

CASE 2.



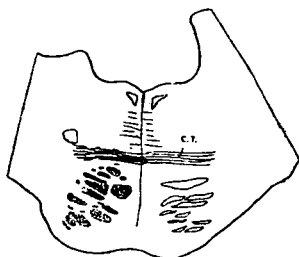
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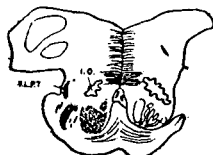
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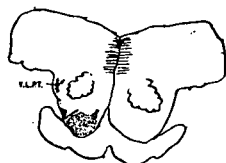
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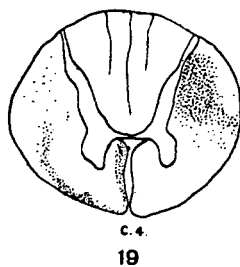
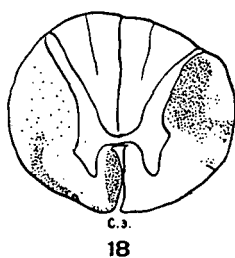
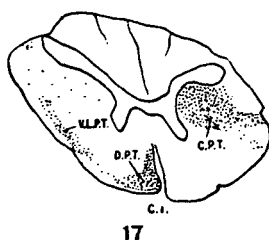
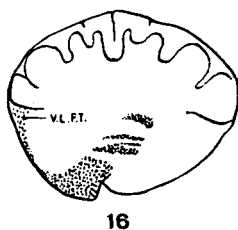
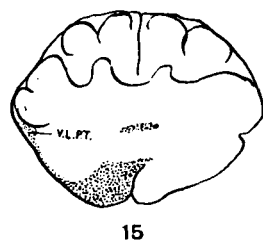
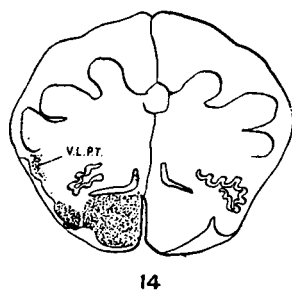
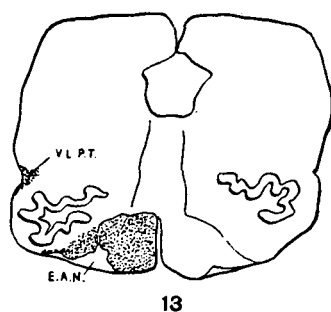
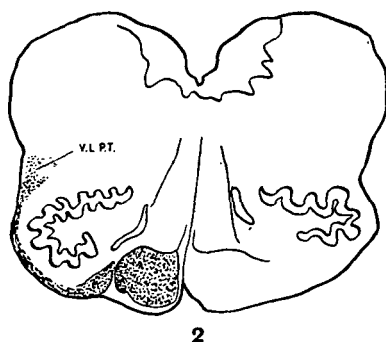
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Figs. 4—8 show the origin and course of the accessory fillet (*A. F.*) and the mesial accessory fillet (*M. A. F.*). Figs. 10, 11 show the origin of the ventro-lateral pyramidal tract (*V. L. P. T.*).

CASE 2.



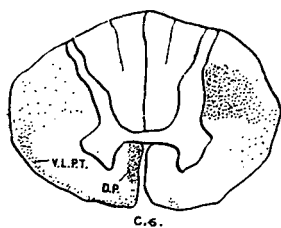
Figs. 12—16 show the arrangement of the pyramid and the ventro-lateral pyramidal tract at various levels of the medulla. Figs. 17—19 show the position of the large ventro-lateral tract in the cord.

The *ansa lenticularis* was degenerated on the left side. Its fibres could be traced from the softened lenticular nucleus curving below the internal capsule and upwards to the optic thalamus of the same side. Many fibres, presumably belonging to this system, passed transversely through the internal capsule from the lenticular nucleus; most of them ended in the corpus Luysii, but a few passed through or round that body to the optic thalamus proper. The optic tract, the bundle of Vicq d'Azyr and the fasciculus retroflexus of Meynert were not degenerated. Spitzka's bundle formed a loop of degenerated fibres passing from the pyramid in the crus inwards towards the mesial aspect of the middle fillet.

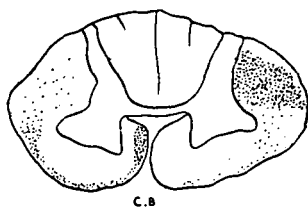
The *pyramidal degeneration* differed only in minor details from that described in case 1 in the internal capsule, mesencephalon and upper half of the pons Varolii. The *accessory fillet* was given off in exactly the same way (case 2, figs. 4 and 5), so that the description in case 1 represents its course with sufficient accuracy. It received many accessions from the thin layers of pyramidal fibres lying subjacent to the middle fillet, and was in the main distributed to the motor nuclei of the fifth and the facial nuclei, chiefly those of the same side, partly those of the opposite side. Many fibres to the opposite nuclei could be seen splitting off from the innermost bundles of the pyramid, and passing up the raphé crossed to the opposite side and turned horizontally outwards on reaching the tegmentum. Many pyramidal fibres were in this way distributed also to the hypoglossal nuclei—chiefly of the opposite but partly of the same side; but no accessory fillet fibre could be traced as low down as this level. There was again no degeneration in the interolivary region beyond the fibres distributed by the pyramid to the medullary nuclei.

Below the corpus trapezoides the appearance of the pyramids differs considerably from that seen in case 1. The bundles in case 2 are smaller and more scattered, and in the lowest sections of the pons (case 2, fig. 10) one bundle is seen to be lying in a dorso-lateral position apart from the other bundles, and on a horizontal level with the upper end

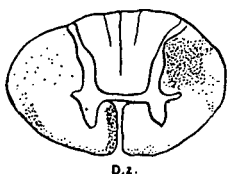
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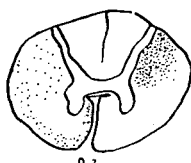
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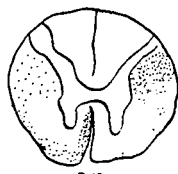
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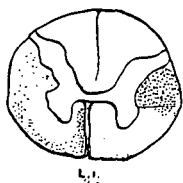
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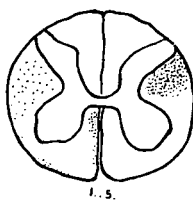
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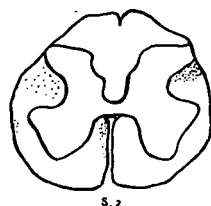
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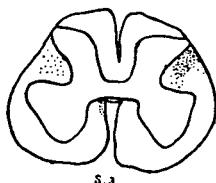
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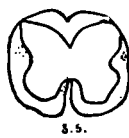
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Figs. 20-30 show distribution of ventro-lateral pyramidal tract (V. L. P. T.).

of the inferior olive. This bundle, the ventro-lateral pyramidal tract, continues to remain distinct from the rest of the degeneration, but certain fibres, cut longitudinally in cross sections, are seen to be passing between the two, forming a connecting link around the inferior olive (case 2, fig. 12).

The majority of these fibres now form a bundle which corresponds closely in position with Gowers' tract, and this association they retain almost to their distribution. At the decussation of the pyramids a large direct pyramid is left behind, whilst the ventro-lateral pyramidal fibres spread out on the periphery of the cord occupying the whole region from the direct pyramidal to the direct cerebellar tracts (case 2, fig. 18). It will be noticed, however, that many of the more dorso-lateral of the fibres are not placed at the periphery of the cord, but lie somewhat deeper, the degeneration here fading off into the slightly degenerated crossed pyramid of the left side.

The lateral uncrossed fibres of the crossed pyramid are about the same in number as in case 1, and arise from the decussating pyramid as a distinct bundle. There are a few degenerated fibres in the ventral pyramid of the opposite (right) side, and along the edge of the cord in the ventro-lateral region.

The crossed pyramidal tract and lateral uncrossed fibres could be traced to the coccygeal region; the direct pyramidal, as a definite bundle, as low as the third sacral, and the ventro-lateral tract as low as the fifth lumbar.

Pick's bundle was not degenerated.

Case 3.—Clinical history. Edgar W. was admitted to the National Hospital, on April 17, 1900, with symptoms of cerebral tumour of about five months' duration. On April 28, 1900, he was trephined in the left temporo-parietal region, a piece of bone about 3 inches square being removed; the dura was opened and the brain—which was evidently under great pressure—bulged considerably. The scalp was sutured over it. The wound healed well.

After the operation the cerebral hernia gradually increased in size until, at the time of his death on January 8, 1901, the hernia formed a mass almost as large as the head. There was complete

hemiplegia and aphasia for six months before death, whilst since October, 1900, consciousness had become progressively less, deepening into coma for the last three weeks.

CASE 3.

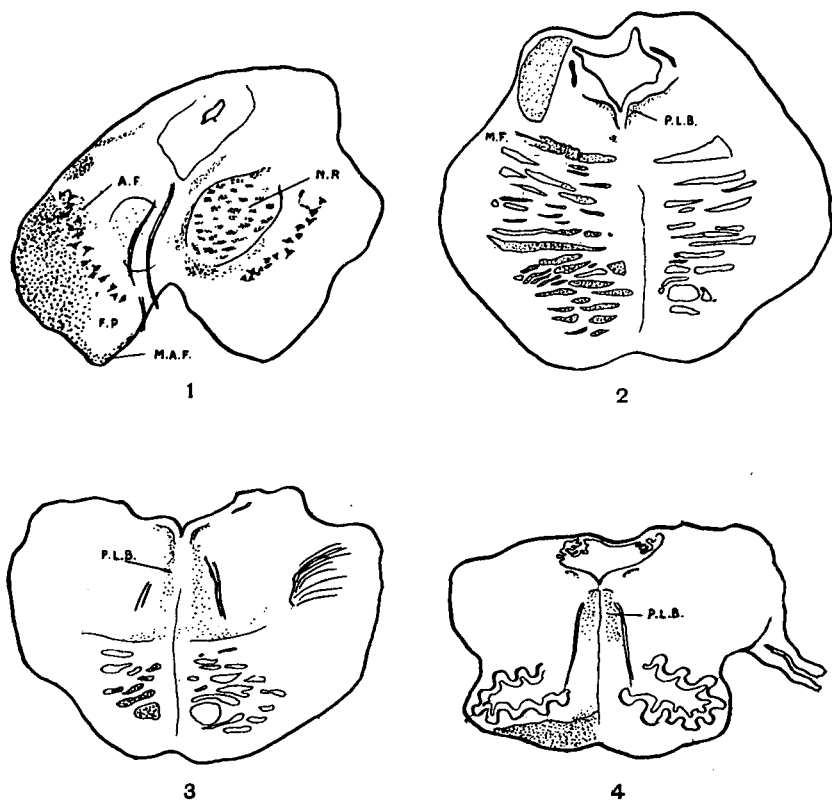


Fig. 1 shows degeneration of the accessory fillet (A. F.) and the mesial accessory fillet (M. A. F.). Both posterior longitudinal bundles (P. L. B.) are degenerated.

AUTOPSY.—The hernia was a carcinoma which had involved almost the whole of the left cerebral hemisphere and basal ganglia, the corresponding cerebral peduncle being much elongated and thinned.

A small portion of the occipital lobe and the most anterior of the frontal convolutions were intact; the island of Reil, lenticular nucleus, internal capsule (genu and posterior limb), caudate nucleus and upper part of the optic thalamus were almost completely destroyed by the growth. The most anterior of the fibres of the anterior limb of the internal capsule were spared. No other gross lesion was found in the nervous system.

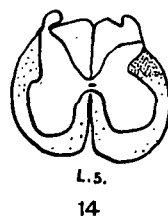
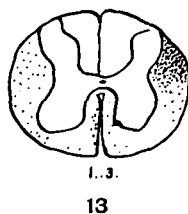
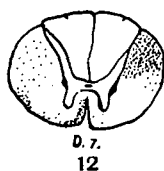
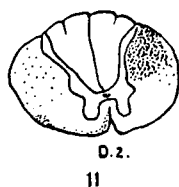
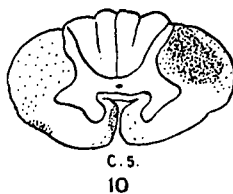
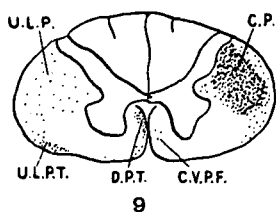
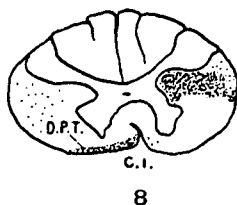
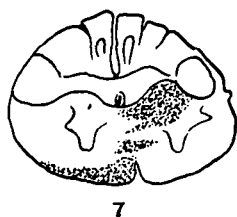
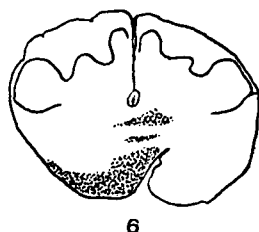
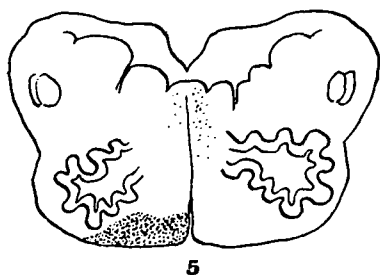
THE DEGENERATIONS.—Owing to the degeneration being of long standing, the Marchi staining is not so clear and brilliant as in cases 1 and 2, and it is impossible in the mid-brain and pons to follow out individual fibres or small tracts: in the cord and medulla the degenerations stained well.

Sections through the internal capsule show that the only fibres free from degeneration are the most anterior of the frontal ones. A mass of degenerated fibres passes to the opposite optic thalamus, in the red nucleus of which they form fine bundles of degeneration as well as a sort of fleece on its inner side (case 3, fig. 1). A few fibres also pass to the red nucleus of the same side.

Another bundle of fibres is seen passing from the outermost part of the capsule towards the corpus quadrigeminum anterior of the same side. The posterior longitudinal bundle of the opposite side is also partly degenerated. A few degenerate fibres are seen in the corresponding bundle of the left side, and both these sets of fibres can be traced through the pons to the medulla oblongata, when they become diffuse and are lost in the interolivary layer.

The accessory fillet.—As in cases 1 and 2 some of the fibres of the internal capsule lying immediately outside the pyramid become detached from the rest of the degenerated bundles, and at the uppermost level of the pons lie in a compact bundle at the junction of the crusta and the tegmentum, near the periphery; later they pass inwards and become diffused among the fibres of the middle fillet; some are seen to cross the middle line and for a time lie in the opposite middle fillet, but their further destination cannot be traced. Spitzka's bundle was also degenerated

CASE 3.



The ventro-lateral pyramidal tract in this case arises from the direct pyramidal tract (*D. P. T.*) at the level of the first cervical segment (figs. 8 and 9).

in this case, and took a similar course to that described in case 1.

In the upper part of the medulla the left pyramid is wholly degenerated, many of the fibres being represented by vacuoles and the rest showing as black dots. There is some scattered degeneration in the interolivary region, partly derived from the diffusing fibres of the posterior longitudinal bundles, and perhaps partly from the descending fillet degeneration.

The pyramid in the medulla remains of a more or less triangular shape until it begins to decussate with its fellow. The crossed pyramid is then formed in the usual way, and after the homolateral fibres have been given off a mass of fibres is left behind lining adjacent portions of the mesial and ventral aspects of the left side of the medulla. This mass of fibres retains this L-shaped form until it reaches the first cervical segment, when it divides into two portions; the larger—the direct pyramid—remains lining the mesial aspect of the ventral fissure, whilst the smaller (about one-half to one-third the size of the former) passes sharply outwards along the edge of the cord to reach the ventro-lateral region. A little lower down these fibres (which evidently correspond to what in cases 1 and 2 was called the ventro-lateral pyramidal tract) assume a triangular shape with the base at the periphery of the cord and the apex pointing towards the central canal. The tract is here massed around a deeply-marked fissure—the most evident fissure, in fact, in the ventro-lateral region of the cord, and they do not form a pure degenerated tract, but are situated amongst a rather larger number of healthy fibres (case 3, fig. 9). They can readily be traced downwards as forming a well marked tract as low as the fifth dorsal segment, and always preserving a more or less flattened triangular shape in the same region of the cord. Below this level the fibres become scattered, but individual fibres are seen down to the lumbar region. In its course the tract is seen to consist of both coarse and fine fibres, the fine predominating.

The direct pyramidal tract ends at the second lumbar segment. The crossed pyramidal tract can be traced to

CASE 4.

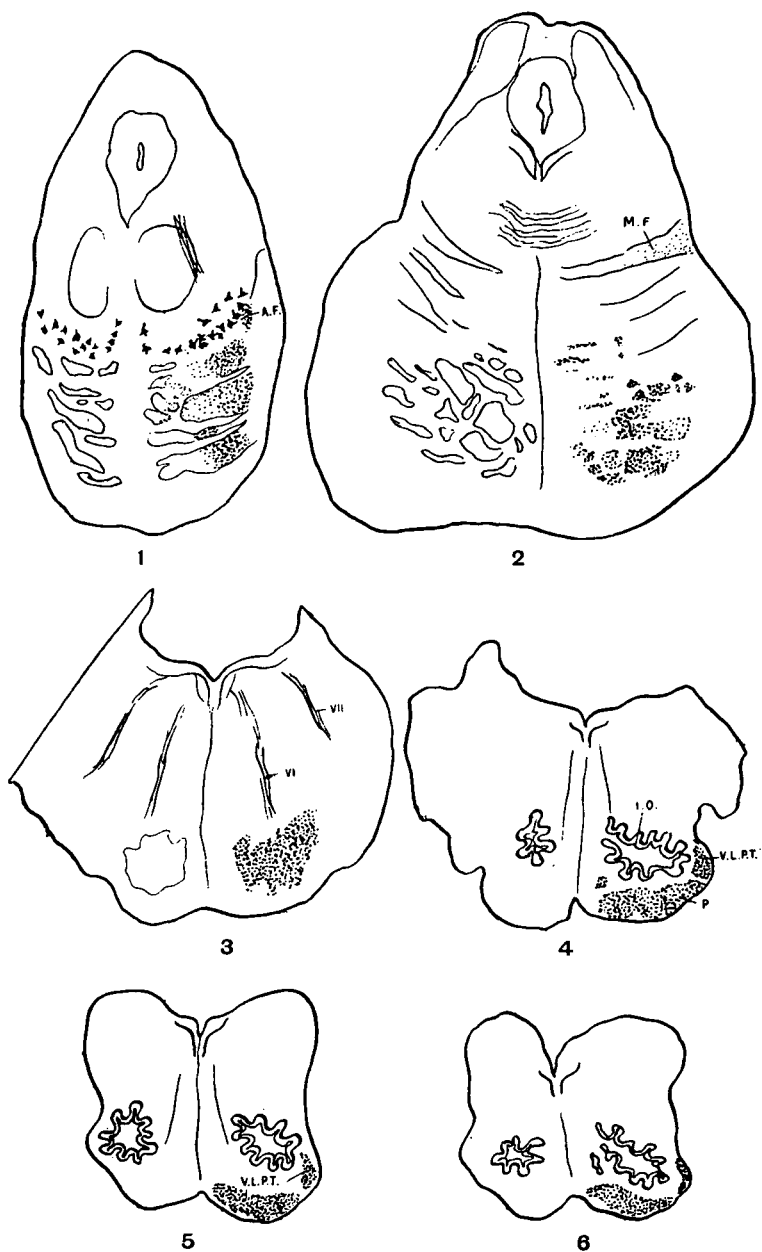


Fig. 1 shows the origin of the accessory fillet (*A. F.*), and fig. 2 its diffusion among the fibres of the middle fillet (*M. F.*). The ventro-lateral pyramidal tract (*V. L. P. T.*) arises in the upper part of the medulla (fig. 4).

the lowest sacral region, and the homolateral fibres of the crossed tract can be traced almost as far.

There were no fibres in the opposite direct pyramid. A considerable amount of posterior column degeneration—apparently due to certain posterior roots—is not figured in the diagram; none of this could be traced above the gracile and cuneate nuclei.

Case 4.—Clinical history. John R. was admitted to the National Hospital, under Dr. Bastian, on July 4, 1900, with signs and symptoms suggesting a focal lesion in the right motor area. He was trephined in the right fronto-parietal region on September 5, but no lesion was then found.

He gradually became more and more hemiplegic, but up to the time of his death preserved to a considerable extent all movements of face, arm and leg. Death occurred suddenly on January 5, 1901, during a convulsion.

AUTOPSY.—A large chronic abscess was found in the right fronto-parietal region. At the region of the trephine hole the abscess wall was attached to the dura mater, but elsewhere the abscess was buried in the cerebrum. The deepest part of the abscess reached the level of the corpus callosum; the basal ganglia on both sides being macroscopically intact.

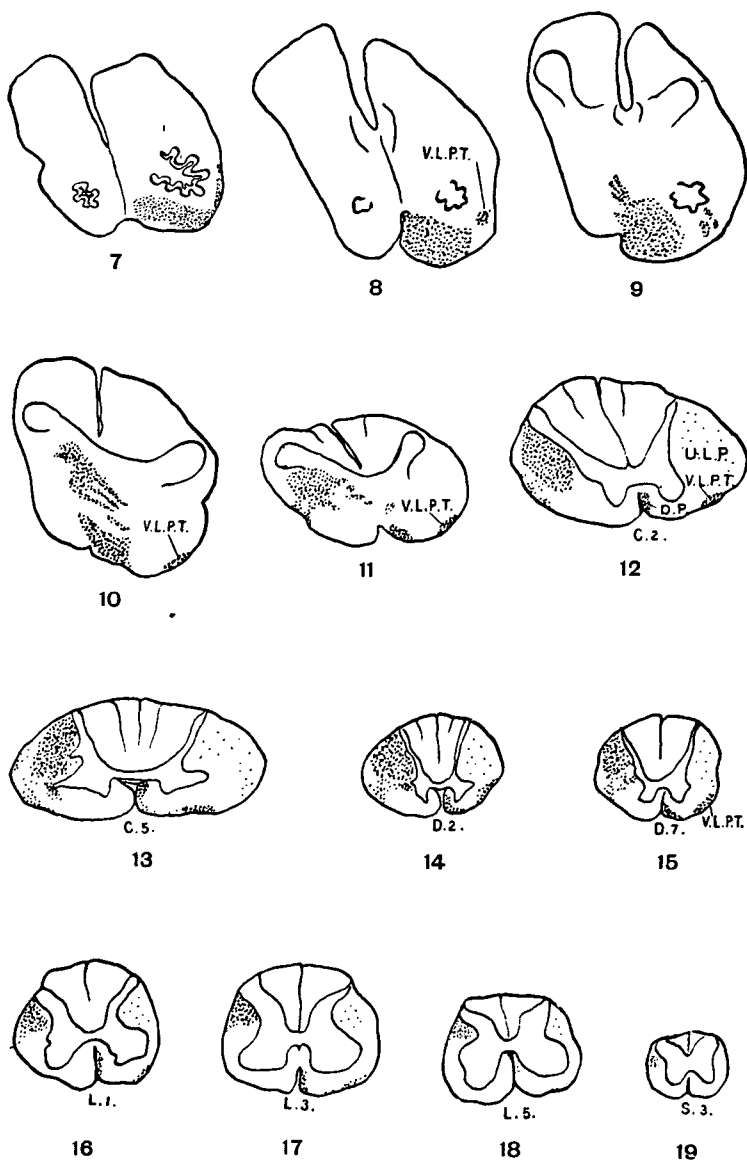
No other gross lesion of the nervous system could be made out.

THE DEGENERATIONS.—In this case the resulting degenerated fibres did not stain so clearly as in cases 1 and 2, so that in the pons individual fibres could not easily be traced. Microscopical examination confirmed the view that the optic thalamus was not involved in the lesion, but parts of the caudate and lenticular nuclei, and much of the internal capsule, were destroyed.

There was a heavy degeneration of the pyramidal fibres in the right crus cerebri, and some, but probably not many, of the frontal fibres were affected. In the main the temporal fibres were intact.

The behaviour of the pyramid in the pons corresponds fairly closely to that observed in cases 1 and 2, and needs no special description.

CASE 4.



Figs. 7—19 show the distribution of the ventro-lateral pyramidal tract (V. L. P. T.).

The *accessory fillet* begins to separate from the pyramid at the lowest level of the mesencephalon, and forms a well-marked bundle of fibres which, at the upper part of the pons, partly mingles with the outermost cells of the substantia nigra. Lower down the fibres quickly mingle with those of the middle fillet, forming at first a diffuse degeneration in its outer two-thirds; the fibres then become aggregated into small bundles, and are seen as such in sections at the level of exit of the fifth nerve. They pass into the tegmentum, but the staining was not sufficiently clear to trace any fibres to their nuclei of distribution. The accessions to these fibres from the more dorsal of the pyramidal bundles of the pons are not so marked as in cases 1 and 2.

Pick's bundle was not degenerated. The *ventro-lateral pyramidal tract* is given off at the lower part of the pons varolii. The pyramid here forms a single compact bundle of degenerated fibres. The most dorso-lateral of the fibres quickly becomes separated by a slight interval from the other fibres (case 4, fig. 4), so that when the inferior olive appears, the ventro-lateral pyramidal tract forms a triangular bundle of degeneration, covering the outer surface of the olive not quite in contact with the apex of the triangle formed by the pyramid proper. This position the ventro-lateral tract maintains throughout the medulla oblongata, varying in shape but never re-uniting with the pyramid. In the upper part of the cervical region of the spinal cord (case 4, fig. 11) it forms a lenticular mass at the periphery which can be traced as a definite tract as low as the third lumbar segment, a few fibres being visible in the sacral region. Most of the fibres seem to be given off at the cervical and lumbar enlargements, but some diminution occurs throughout the dorsal region.

At the decussation of the pyramid, a rather large direct tract is left behind, and the lateral uncrossed fibres arise as a well defined bundle. The direct tract can be traced as a definite bundle visible to the naked eye as low as the first sacral segment.

The shape of the crossed pyramid was in the main

similar to that described in cases 1 and 2, but the clump of fibres at the periphery in the ventro-lateral region is here more distinct and comes further towards the ventral fissure. It lies, however, further outwards than the uncrossed ventro-lateral tract and has also a different shape; nor can it be traced as far down, ceasing about the second dorsal region. The crossed tract can be traced down to the coccygeal region.

Case 5.—Clinical history. George D., aged 57, was admitted to the National Hospital on June 19, 1901, under Dr. Ferrier. Three weeks before admission there was a sudden onset of weakness in the right hand; within six hours the right upper and lower extremities were paralysed and speech was a little awkward, and twelve hours later he could not speak or use the right arm or leg.

On admission he was quite helpless and in a generally weak condition; mentally he was dull and drowsy, but appeared to understand simple sentences. The right arm and leg were completely paralysed, and the right side of the face (in the lower segment) was equally paralysed for voluntary and emotional movements; no face movement on either side could be obtained in association with a strong grip, &c. The tongue deviated markedly to the right. Hemianæsthesia and hemianopia were well marked. He gradually became weaker and died comatose on June 27, no appreciable change having occurred in the motor condition.

AUTOPSY.—There was extensive vascular disease, especially in the arteries of the circle of Willis. The left middle cerebral artery was blocked by a cartilage-like clot, and there was extensive softening in the left hemisphere. Superficially only a circular patch on the left upper frontal convolution (about an inch in diameter) was softened; but sections showed that much of the hemisphere was softened, the caudate and lenticular nuclei being almost wholly and the upper part of the optic thalamus partly involved. The lesion did not extend into the red nucleus. Of the internal capsule, only part of the anterior genu remained intact.

THE DEGENERATIONS.—The thalamic and hypothalamic regions were not stained. In the upper pontine region

there was well-marked degeneration of the pyramidal and temporal fibres, whilst the *accessory fillet*, pursuing a course very similar to that described in case 1, caused a very heavy degeneration to appear in the middle fillet, so that at the

CASE 5.

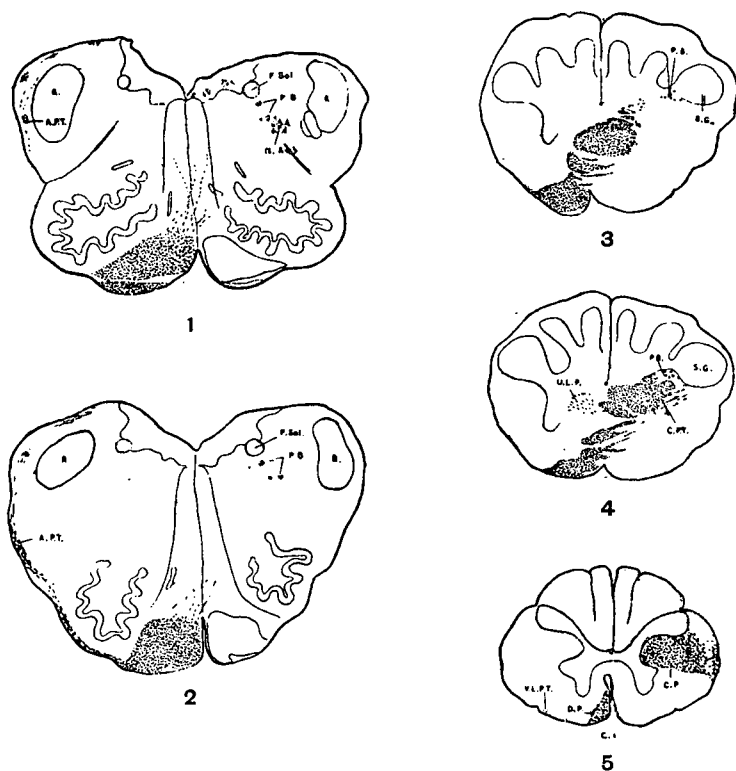


Fig. 4 shows the origin of Pick's bundle, which passes upwards and becomes scattered in the upper sections of the medulla (figs. 2 and 1). A few fibres only represent the ventro-lateral pyramidal tract (*V. L. P. T.*, fig. 5). An aberrant tract (*A. P. T.*) arises from the pyramid in 2 and passes upward to reach the floor of the fourth ventricle (fig. 1). Many fibres leave the pyramid in figs. 1 and 2 to pass through the interolivary layer to the hypoglossal nuclei.

level of the decussation of the trochlear nerves, about one-fourth of the fillet fibres were degenerated. The arrangement of the fibres into bundles, their mesial direction and

distribution to the motor fifth and seventh nuclei of both sides were all well marked and need no special description. No fibres could be traced to either hypoglossal nucleus.

Pick's bundle was very well marked in this case. The fibres first begin to appear (on the side opposite to the degeneration) in the lowest sections of the pons, and are situated just dorsal to the facial nucleus, between it and the substantia gelatinosa. Here only a few scattered fibres can be seen, but further downwards the bundles progressively increase in size and compactness, and lie between the nucleus ambiguus and the fasciculus solitarius, a little ventral to the latter (case 5, figs. 1 and 2). At the level of the decussation of the fillet, five or six well-marked bundles are seen close together just mesial to the substantia gelatinosa, and at the decussation of the pyramids the bundles—still not completely fused together—become lost in the crossed pyramid. For several sections, however, they can be traced as definite bundles and in transverse sections are cut obliquely just before they are lost, giving the appearance of partly turning inwards towards the direct pyramid of the opposite side at this point. In this case, more than in case 1, the appearance is that of a tract arising by the curling upwards of fibres just crossed over from the opposite side, and being distributed to the nucleus ambiguus and adjacent nuclei (? facial nucleus) of the same side. In no section could any degenerated fibres be seen crossing from the opposite fillet or pyramid to *Pick's bundle*, and as nearly every section was so examined, and the degeneration was very well marked, it seems certain that very few, if any, of the fibres could have had such an origin.

The *ventro-lateral pyramidal tract* was represented by a few scattered fibres only in the first cervical segment; none were seen below that point.

Another curious set of homolateral fibres was given off from the pyramid just above the middle of the olive (case 5, fig. 2). They passed upwards and outwards as a thick band of degenerated fibres round the olive with the external arcuate fibres to reach the region of the restiform body, around which they became scattered, the most prominent bands of

fibres being situated near the nucleus cuneatus; two small bundles, however, were almost superficial, and lay close to the surface of the fourth ventricle, and could be traced nearly to the hypoglossal nucleus (case 5, fig. 1).

The crossed pyramidal tract showed no exceptional features, the degeneration at the edge of the cord outside the direct cerebellar tract being well marked in the cervical region.

The direct pyramidal tract was of average size, and could be traced to the lumbar enlargement.

The *lateral uncrossed* fibres came off from the decussating pyramid as a well-marked but rapidly diffusing tract (case 5, fig. 4).

THE VENTRO-LATERAL PYRAMIDAL TRACT.

It will be seen that I have been able to trace in four cases of hemiplegia in man a tract which descends with the pyramid from the cerebral cortex or basal ganglia, at least as far as the pons, and which in the spinal cord is situated in the ventro-lateral region near the periphery; and I venture to suggest that the term "ventro-lateral pyramidal tract" is the most convenient terminology, as showing both the immediate origin and the ultimate position of the tract. This tract consists of a number of small and large fibres which split off as a compact bundle from the pyramid, either in the lower part of the pons or in the medulla, and coursing obliquely outwards come to lie at the edge of the cord in the ventro-lateral region. Occasionally (case 3) they are not split off until after the decussation of the pyramids, and in this case the tract is formed from the direct pyramidal tract of the same side. No case is recorded in which the fibres are given off below the first cervical segment. In all cases the tract is an uncrossed one.

This tract is variable, not only in its size, but in its region of distribution. In most cases the fibres begin to become diffuse at the third cervical segment, and they cease to be a tract in the lower cervical region; but sometimes,

as in cases 2 and 3, they can be traced down to the lumbar region. As a rule it is not more than about one quarter of the size of the direct pyramidal tract, but like the latter it is very variable; it may be completely absent, or as in case 2 it may be almost as large as the direct pyramid itself. For this reason it has been usual for those investigators who have recognised its origin to refer to this tract as an "aberrant" one, but as some fibres of it at least seem to exist in the cervical region in nearly every case of cortical and sub-cortical hemiplegia (as in four consecutive cases of hemiplegia reported in this article), and as in many, if not the majority, of such cases it constitutes a definite tract, I think this appellation is hardly justified, and it would be better to recognise it under the term "tract" as a definite branch of the pyramidal system in man.

The exact origin of this tract I have been unable to determine. From two of my cases it is evident that the fibres lie dorso-lateral to the main mass of the pyramid in the lower pontine region, and supposing, as the sections appear to show, that no serious rearrangement of fibres takes place higher up in the pons, it is probable that they are closely associated with the accessory fillet between the pyramidal and the temporo-pontine fibres in the crus cerebri. Beyond this region it is impossible to trace them: but it is quite evident that they are derived either from the Rolandic or closely adjacent cerebral cortex, or from the caudate or lenticular nuclei: they certainly do not arise in the optic thalamus. I am inclined to think that they have a cortical origin, but of this I have no actual proof.

Many cases have been reported in the literature in which it is evident that some of the fibres seen degenerated belong to this tract. *Meyer*,¹ in 1882, describes a case of extensive pontine hæmorrhage in which there was degeneration in the ventro-lateral region of the cervical cord. From his drawings it is probable that the vestibulo-spinal tract, the thalamo-spinal, ponto-spinal and some pyramidal fibres go to make up his degeneration, which was well-marked by the Weigert method. For fine degeneration in this region, however, the Weigert and carmine methods are of little

value, because in the upper cervical segments the ventro-lateral region does not stain so deeply as the other columns; this appears to be partly owing to the fineness of many of its fibres and partly to the greater amount of interstitial tissue present here. This area which, like the tract under discussion, is triangular in shape, has been called the "Dreikantenbahn" by *Helweg*,² and, as is well figured in Bruce's "Atlas of the Spinal Cord," represents a normal structure. The recent work of *von Bectereu*³ shows that these fine fibres are derived from the inferior olive (the "fasciculus peri-olivaris"). It is therefore clear that the Marchi method alone is of value as indicating the presence of comparatively slight degeneration in this region, and it is of little use to speculate upon the value of the older observations in connection with this tract.

In several recent papers reference has been made to the fibres. *Risien Russell*,⁴ in 1898, in a case of left hemiplegia due to sarcoma of the right cerebral hemisphere, figured a small tract at the decussation of the pyramids lying lateral to the pyramid itself: the fibres were distinct from the degenerate pyramid, "but did not appear to be derived from this source." Unfortunately sections through the pons are not figured, but the fibres occupied the ventro-lateral column of the cord, and there is little doubt that this was a ventro-lateral pyramidal tract.

Mott and Tredgold,⁵ in 1900, described and figured, in a case of thrombosis of the middle cerebral artery, a tract in the ventro-lateral region of the uppermost cervical segments, and traced it as far as the lumbar enlargement. They say: "We are inclined to think . . . that its probable origin is the optic thalamus; that it passes through the middle fillet in the pons and the interolivary lemniscus in the medulla to reach the peripheral part of the antero-lateral column of the cord, in which it descends as far as the lumbar region." This suggestion was, the authors say, made after consideration of the results of *Hoche's*⁶ work, to which reference will be made later. The pons and medulla do not appear to have been available for Marchi sections. I cannot think that the tract seen in the ventro-lateral region had

this origin or course. In *Hoche's*⁶ cases, as in one of mine (case 3), it is true that there was degeneration in the fillet in the interolivary region; but Hoche figures no degeneration in the ventro-lateral region of the cervical cord, nor could any of these fibres in case 3 be traced to this region; and in cases 1, 2 and 4 there was no interolivary degeneration and yet a well-marked ventro-lateral tract existed. The recent work, too, of *Collier and Buzzard*⁷ shows that the thalamospinal tract in man, although corresponding fairly closely with this tract in the cervical cord, lies in the tegmental region of the pons dorso-lateral to the middle fillet, and that to reach this position it passes outside the olive and not through the interolivary fillet. Although, therefore, I cannot deny the possibility of the thalamic origin suggested by Mott and Tredgold for the tract in their case, the evidence is all in favour of its having had a pyramidal origin and of its having been independent of a possible interolivary degeneration.

Spiller,⁸ in 1899, in a case of hæmorrhage into the lenticular nucleus and external capsule, also found this tract. In his case the fibres, separated from the pyramid in the lower pontine region, passed downwards amongst the fibres of Gowers' tract opposite the olive. They were not traced beyond the first cervical region as the rest of the cord was not available. He concluded that they arose either in the Rolandic area, the lenticular nucleus or optic thalamus, and tended to the view that they were not an "aberrant" but a constant tract.

Mme. Déjérine,⁹ in 1900, described fibres in the ventro-lateral region of the cord in hemiplegia due to cortical lesions. These "fibres pyramidales homolatérales superficielles" arose from the pyramid at the middle of the medulla and passed outwards in front of the olive to reach the ventro-lateral position. The author does not state in how many cases these fibres were seen, but refers to them as "aberrant."

EMBRYOLOGY.—Many of the fibres of the ventro-lateral region of the cord become medullated very late—at about the same time as the pyramidal tracts (*Barker*,¹⁰ von

Bectereu³). I have confirmed this observation in the cord of a new-born child, but was unable to pick out the various sets of fibres which probably make up the ventro-lateral column. The late development of this region, however, suggests a similarity in function and origin between its fibres and those of the pyramidal tracts.

COMPARATIVE ANATOMY.—I am indebted to Mr. Victor Horsley for a photograph of the pons and medulla of a badger, in which a band of fibres is seen to be passing superficially from the mesial part of the medulla to the ventro-lateral region, just at the lower edge of the pons.

*Schäfer*¹¹ states that in the monkey a few fibres of the ventro-lateral column degenerate after lesions of the opposite cerebral hemisphere. *Mellus*¹² does not mention any such fibres as degenerating after cerebral cortical lesions in the monkey.

I can find no other references to the existence of a ventro-lateral pyramidal tract in lower animals, despite the number of cases in which extirpations of the motor cortex have been done. It is well known that the direct pyramidal tract is usually small and often absent in monkeys, dogs and cats, and that even in man its variations are extreme, so that there is nothing surprising in these observations about the smaller and probably later-developed ventro-lateral pyramidal tract. The ventro-lateral columns of the cervical region in man are now known to contain the following sets of descending fibres:—

(1) Intersegmental fibres, short and long, originating in the spinal cord.

(2) The fasciculus peri-olivaris (von Bectereu),³ arising in the inferior olive.

(3) The vestibulo-spinal tract (Ferrier and Turner,¹³ Risien Russell⁴) from Deiters' nucleus.

(4) The ponto-spinal tract from the pontine nuclei.

(5) The colliculo-spinal tracts (Boyce,¹⁴ Collier and Buzzard⁷) from the corpora quadrigemina.

(6) The thalamo-spinal tract (von Monakow,¹⁵ Boyce¹⁶) from the optic thalamus: and we may add

(7) The ventro-lateral pyramidal tract, probably from the cortex, possibly from the lenticular nucleus.

Of all these sets of fibres the last to be developed, both phylogenetically and ontogenetically, are the pyramidal fibres, and it is therefore not surprising that they occur only in the highest primates and should in them be variable.

THE ACCESSORY FILLET.

This name was given by *von Bectereu* to a bundle of fibres which lying lateral to the pyramid in the crus cerebri leaves it in the mesencephalon, and coursing dorso-laterally through the outermost cells of the substantia nigra passes into the middle fillet in the upper pontine region. *Schlesinger*¹⁷ called it the "lateral pontine bundle." *Hoche*⁶ also described and figured it in two cases, and his excellent figures of the middle fillet at birth prove that fibres which degenerate in hemiplegia are of much later development than the rest of the fillet fibres. That the accessory fillet is distributed to the motor nuclei of the trigeminal and to the facial nuclei of both sides I can confirm, but I have been unsuccessful in tracing any fibres to the hypoglossal nuclei. No fibres could be traced to the third, fourth or sixth nerve-nuclei, and in this respect my results agree with those of *von Bectereu*, *Hoche*, *Schlesinger* and *Collier* and *Buzzard*.

Most, if not all, of the degeneration seen in the interolivary layer in my cases (except case 3) was due to fibres of distribution from the pyramid to the nuclei of the hypoglossal and possibly to the adjacent nuclei: I could not trace any fibres from the accessory fillet as far as this region, and on this point disagree with the findings of *Hoche*. In case 3 the fibres seen in the interolivary region were largely derived from the posterior longitudinal bundles, but probably here also none were derived from the accessory fillet.

It is interesting to note that the accessory fillet receives accessions of fibres from the most dorsal layers of the pyramidal fibres in the pons, and that these layers, if traced upwards, are seen to lie in the crus between the accessory fillet and the main mass of the pyramid.

I have been so far unable to determine the exact origin of the accessory fillet fibres, as in all my cases not only the Rolandic area (or its corresponding fibres in the internal capsule) was degenerated, but also the lenticular nucleus was more or less involved; the probability, however, is that the fibres originate in the cortex of or near the motor area.

The *mesial accessory fillet* of von Bectereu (Spitzka's bundle) was degenerated in three cases (1, 2 and 3). In each the fibres passed from the pyramid in the crus to the inner end of the corresponding middle fillet; the number of fibres so supplied to the fillet was small compared with those coming from the (lateral) accessory fillet.

PICK'S BUNDLE.

This small tract was first described by *Pick*¹⁸ in 1889. He described it as a rounded, well-marked bundle ascending from the lateral column of the cord at the upper limit of the decussation of the pyramids to end in or near the posterior column nuclei, and possibly sending some fibres to the cerebellum. He only observed it in one case, and was of opinion that it was a rare abnormality.

Hoche,⁶ in 1898, found it degenerated in one of two cases of hemiplegia; he was of opinion that the fibres were descending, and that the bundle was formed by the union of prematurely crossed pyramidal and accessory fillet fibres in the lower pontine and upper medullary regions, and that, as these fibres descended, they were collected together into one or more compact bundles and fused at the decussation of the pyramids with the crossed pyramidal tract, of which it was thus a tributary.

The appearance of the bundle in cases 1 and 5 lead me to differ from *Hoche*. Although nearly every section was examined in the medulla and lower pons, I could find no sign of any degenerated fibres crossing from the opposite fillet or pyramid to join the bundle; and further, the appearance of the bundle as it joins the crossed pyramid strongly supports the view that it is with the latter that the crossing takes place. Further, in all the cases that have been figured, and in my own sections, there is a progressive

two cervical segments; occasionally it can be traced down to the lumbo-sacral region.

(2) I confirm, in the main, the researches of Hoche on the "accessory fillet" in man, *i.e.*, that it leaves the pyramid in the upper pontine region, descends in the middle fillet, and supplies certain of the cranial motor nuclei.

(3) "Pick's bundle" is probably an ascending tract which arises from the crossed pyramid at the decussation, and forms at least part of the pyramidal supply of the nucleus ambiguus; it is fairly frequently degenerated in cases of hemiplegia, and is not of such rare occurrence as Pick supposed.

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EXPLANATION OF ABBREVIATIONS IN FIGURES AND PHOTOGRAPHS.

- A. F. = Accessory fillet.
 A. P. T. = Aberrant pyramidal tract, described on p. 490.
 B. C. = Brachium conjunctivum.
 C. P. T. = Crossed pyramidal tract.
 C. T. = Corpus trapezoides.
 C. V. P. F. = Crossed ventral pyramidal fibres.
 D. P. T. = Direct pyramidal tract.
 Dent. = Dentate nucleus.

- E. A. N.* = External arcuate nucleus.
F. P. = Fronto-pontine tract.
F. Sol. = Fasciculus solitarius.
I. O. = Inferior olive.
M. A. F. = Mesial accessory fillet (Spitzka's bundle).
M. F. = Middle fillet.
N. Amb. = Nucleus ambiguus.
N. Mot. V. = Motor nucleus of trigeminus.
N. R. = Nucleus ruber.
P. = Pyramid.
P. B. = Pick's bundle.
P. L. B. = Posterior longitudinal bundle.
R. = Restiform body.
T. P. = Temporo-pontine tract.
U. L. P. = Uncrossed lateral pyramidal fibres.
V. L. P. T. = Ventro-lateral pyramidal tract.
X. = Tract described on p. 471.
V., VI., VII. = Fifth, sixth and seventh nerves.

The figures were outlined with the aid of the Edinger apparatus, and details filled in from microscopic examination.