THE CROONIAN LECTURES

ON

CEREBRAL LOCALISATION.

Delivered before the Royal College of Physicians of London.

By DAVID FERRIER, M.D., LL.D., F.R.S.,

Physician to King's College Hospital, and to the National Hospital for the Paralysed and the Epileptic, Queen Square.

Lecture I: Introductory.

Mr. President and Gentlemen,—While highly appreciating the distinguished honour of being appointed Croonian Lecturer of the College of Physicians, I must confess to having undertaken the onerous duties of the office with considerable hesitation and trepidation, for, though the subject which I have chosen is one to which I have devoted a good deal of attention, and which, in one of its aspects, namely, The Localisation of Cerebral Disease, I have already had the honour of discussing before you as Goulstonian Lecturer, yet, considering the enormous amount of work that has been done in this department in recent years, and the numerous problems which still remain unsolved, I have felt that, with my other duties, time and strength would scarcely permit me to do justice to my subject. I could not feel satisfied with merely repeating the views which I have elsewhere, and at various times, expressed on this subject, and which, to many of you at least, are sufficiently well known; therefore it seemed necessary that I should, for the purpose of these lectures, undertake new investigations, in order to throw light, if possible, upon some of the points which are still in dispute. But to compress into practically a few months of otherwise fully occupied time what might well be the undivided labour of a long period has proved a difficult task, and I have fallen far short of what I had hoped to accomplish, though I trust that some of the results at which I have been able to arrive may contribute towards a solution of some of the vexed questions. I purpose in these lectures to sketch the evolution of the doctrine of cerebral localisation, to indicate the principal data on which it is based, and to discuss, in the light of the most recent investigations, the evidence for and against the existence of specific centres, and their exact position in the cerebral cortex.

Before considering the facts bearing directly upon the specific localisation of function in the cerebral cortex, I think it advisable —nay, even necessary—to consider the effects of ablation of the cerebral hemispheres in different classes of animals. A due consideration of these phenomena affords, I think, a satisfactory explanation of the chief objections which have been urged against localisation in general, and, at the same time, also renders unnecessary certain hypotheses as to the functional substitution of one part of the cortex by another, which have been—and, in my opinion, rightly—regarded by the opponents of localisation as altogether subversive of its fundamental principles.

Recent researches on the effects of the removal of the cerebral hemispheres by improved methods have necessitated some important modifications of the doctrines which, up to quite a recent date, have been generally entertained on the subject.

Let us begin with fishes. When in osseous fishes the ganglia (which correspond morphologically to the cerebral hemispheres of the vertebrates) are entirely removed, there is little, if anything, to distinguish them from perfectly normal animals. They maintain their natural attitude, and use their tails and fins in swimming with the same vigour and precision as before. It has generally been said that brainless fishes possess no spontaneity, but seem as if impelled by some irresistible impulse (occasioned by the impressions communicated to the surface of their bodies by the water in which they are sustained) to swim until they are exhausted by pure neuro-muscular fatigue. In their course, however, as was shown by Vulpian, they do not blindly rush against obstacles, but turn to the right or left, according to circumstances, as if still possessed of some sense of vision. Vulpian says[1] "In fact, when the cerebral hemispheres have been removed from a fish which does not readily succumb to this kind of operation (a roach, for example), not only may it be urged to move by bringing an object before its eyes, but I have proved that it avoids obstacles; for, by placing a stick to the right or left, a few centimètres from its eye, I have frequently caused the fish to turn in the opposite direction."

[1] *Système Nerveux*, p. 669.

Steiner[2] does not admit the absence of spontaneity in fishes so operated upon, for he has seen that they occasionally remain at the bottom, at other times balance themselves at various heights in the water, and now and then swim about freely, without any obvious alterations in the conditions by which they are surrounded. He has also shown, and in this he has been confirmed by Vulpian[3] that they not only see, but are able to find, their food. If worms be thrown into the water in which they are swimming, they immediately pounce upon them. If a piece of string similar in size to a worm be thrown in, they are able to detect the difference, and either disregard it entirely, or drop it after having seized it. Not only do they seize their food, but they discriminate between different kinds, selecting some, and rejecting others. They even to some extent distinguish colours, for when one red and a few white wafers are thrown into the water, the fish almost invariably selects the red in preference to the white.

From these facts it would appear that the fish without cerebral hemispheres can see, distinguish colours to some extent, catch its prey, discriminate between different kinds of food, direct its movements with precision, and, in fact, behave to all appearance like a normal animal. The only difference observed by Steiner was that brainless fishes appeared more impulsive and less cautious than those which had not been operated upon.

What has been said above applies, however, only to Teleosteous fishes. Quite different results appear to follow removal of the cerebral hemispheres in Elasmobranchs. Thus the dog-fish, according to Steiner,[4] after this operation is entirely deprived of spontaneity, and is quite unable to find the food (sardines) by which it is surrounded. The difference between the two orders of fishes is, however, more apparent than real, for the dog-fish is guided mainly by its sense of smell, while the activity of the osseous fish is conditioned more especially by vision; hence, in the dog-fish, removal of the cerebral hemispheres, which are almost exclusively related to the sense of smell (Fig. 1.—a),

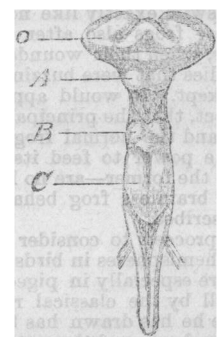

Fig. 1.—Brain of dog-fish (after Steiner). a, cerebral hemisphere; b, optic lobe; c, cerebellum; o, olfactory lobe.

abolishes all the reactions conditioned by this sense; while in the osseous fish, the primary visual centres (optic lobes), being intact, the ordinary modes of activity, which are conditioned mainly by the eyes, continue to all appearance unmodified.

Frogs.—According to the researches, more particularly of Goltz[5] and Steiner,[6] frogs deprived of their cerebral hemispheres behave, *cæteris paribus*, essentially like fishes similarly treated; they maintain their normal attitude, and resist all attempts to overthrow their equilibrium. If laid on their backs they will turn over and attempt to regain their ordinary position. If the basis of support on which they rest is tilted in any direction, they will clamber up, forwards, or backwards until they gain a position of stability. Their powers of locomotion are retained, and their limbs are co-ordinated with precision. If a foot be pinched, or any irritation applied to the posterior part of the body, they will hop away; thrown into the water they will swim, and continue swimming until they have reached the side of the vessel, up which, if possible, they will clamber and rest in peace. It would

[2] *Die Functionen des Centralnervensystems: Zweite Abtheilung: Die Fische*, 1888.
[3] *Comptes Rendus.* Tome 102 and 103, 1886.
[4] *Op. cit.*
[5] *Functionen der Nervencentren des Frosches*, 1869.
[6] *Physiologie des Froschhirns*, 1885.

in fact be difficult, so far as their movements and response to peripheral stimuli are concerned, to distinguish between a normal and a brainless frog. If the back be gently stroked the frog will answer uniformly with a croak, as if of pleasure or enjoyment. If the animal be put in a vessel containing water, the temperature of which is gradually raised, it will jump out as soon as the bath becomes uncomfortably hot. If placed at the bottom of a pail of water, it will ascend to the surface to breathe. If the vessel be inverted over a pneumatic trough and filled with water, sustained by barometric pressure, the frog will ascend to the top as before, but not finding there the oxygen necessary to satisfy its respiratory craving, it will work its way downwards, and ultimately succeed in making its escape out of the vessel on to the free surface of the trough. Like the fish, the brainless frog undoubtedly possesses some form of vision; it does not, when urged to move, rush blindly against an obstacle, but will leap over it, or turn to the right or left, or otherwise avoid it. In all these respects a brainless frog behaves like a normal one, but one noteworthy difference has been signalised by most observers—namely, that the brainless frog, unless disturbed by some form of peripheral stimulus, will remain for ever quiet on the same spot, until, in fact, it becomes dried up and converted into a mummy. All spontaneity—that is, varied activity under apparently the same external conditions—appears to be annihilated; its past experience has been blotted out, and it views with indifference signs and threats which would formerly have made it flee. It is also generally stated that the brainless frog has lost its instincts of self-preservation, and either feels no hunger or possesses no power to satisfy its physical necessities, so that it dies in the midst of plenty. The more recent experiments, however, of Schrader[7] would seem to show that removal of the hemispheres deprives the frog neither of spontaneity, nor of special instincts, nor of the ability to feed itself; for he has observed brainless frogs which have been kept alive for long periods, apparently "spontaneously" jump from the pier of a galvanometer, absolutely free from all tendency to vibration, alternate between land and water in the aquarium, crawl under stones, or bury themselves in the earth at the beginning of winter, and, when cautiously submerged under water, begin to swim exactly like normal frogs under the same conditions. These frogs also, after the period of hybernation, or in the summer, when their wounds were entirely healed, diligently caught the flies that were buzzing about in the vessels in which they were kept. It would appear, therefore, if these observations are correct, that the principal points of distinction between the brainless and the normal frog—namely, the absence of spontaneity and the power to feed itself, which are said to especially characterise the former—are no longer capable of being upheld, and that the brainless frog behaves precisely like the brainless fish above described.

Birds.—Let us now proceed to consider the effects of the removal of the cerebral hemispheres in birds, the next higher class of vertebrates, and more especially in pigeons. These have been rendered familiar to all by the classical researches of Flourens;[8] but though the picture he has drawn has been accepted as in the main correct, there have been, and there still are, some differences of opinion as to the facts, and more particularly as to their mode of interpretation. There is, however, no doubt that after this operation pigeons show no disturbance of station or locomotion. They maintain their normal attitude, and resist all attempts to overthrow their balance. Left to themselves they appear, at first at least, to be plunged in profound sleep. From this condition they are easily aroused by a gentle push or pinch. When so urged they march forwards, and should they happen to step over the edge of the table, on which they are placed, they will flap their wings and regain their base of support. Thrown into the air they fly with all due precision and co-ordination. After each manifestation of activity so induced they subside into their original state of repose. Occasionally, and apparently without any external stimulus, they may look up and yawn, shake themselves, dress their feathers with their beaks, move a few steps forwards or backwards, especially after defæcation, and then settle down quietly, standing sometimes on one leg, sometimes on the other. They are altogether unable to feed themselves; but, if fed artificially, deglutition, digestion, and nutrition go on in a normal manner, and the animals may be kept alive for an indefinite period. Flourens was of opinion that the removal of the cerebral hemispheres annihilated all the senses, and rendered the animals blind, deaf, and devoid of smell, taste, and tactile sensibility. These conclusions were, however, disputed by Magendie, Bouillaud, Cuvier, and, in particular, by Longet[9] and Vulpian.[10] Longet found that the animals appeared to see, inasmuch as they would follow the movements of a flame held in front of their eyes at a sufficient distance to prevent all sensation of heat, and also when urged to move, occasionally at least, avoided obstacles in their path. Also they started at loud sounds, such as a pistol shot, made in their immediate vicinity; and from their movements and gestures appeared to feel impressions made upon the nerves of common sensation. As regards the senses of taste and smell, he found it impossible to arrive at any definite conclusions in animals of this order, and looked upon the statements of Flourens as not supported by convincing evidence. Longet believed that the removal of the cerebral hemispheres annihilated only perception proper, as distinct from crude or brute sensation, which had its centre in the mesencephalic ganglia.

The question as to the sense of sight in brainless pigeons has been much discussed, that is, whether not mere impressionability to light exists, but as to whether the animals see, in the sense of being able to guide their movements in accordance with their retinal impressions. McKendrick[11] was of opinion that removal of the one cerebral hemisphere caused blindness in the opposite eye; and Jastrowitz,[12] from his own experiments, arrived at the same conclusion (on this see further below). The experiments of Blaschko,[13] under the direction of Munk, led to no very definite conclusions on this point, though it seemed as if the removal of the one hemisphere did not cause total blindness in the opposite eye. But Munk himself[14] has made it the subject of a considerable number of experiments. He found that in a certain number of pigeons, from which he had attempted to remove the cerebral hemispheres, vision was not entirely abolished, and the animals were able to avoid obstacles placed in their path. Careful investigations, however (*post mortem*) revealed the fact that in such cases the hemispheres had not been entirely destroyed, vision continuing to some extent in the eye opposite the hemisphere, the extirpation of which had not been absolutely complete. In those cases, however, in which not a trace of either hemisphere was allowed to remain, blindness was complete and absolute. These animals, in their attitude and reaction to peripheral stimuli, etc., exhibited the symptoms already described. The brightest light, however, caused no result beyond contraction of the pupil. The animals, when urged to move, ran against every obstacle which came in their way. When thrown into the air, they flew with retracted head and half-raised trunk, outstretched legs, and dashed against obstacles, or fell bump on the ground and slid a considerable distance before coming to a standstill.

The phenomena described by Munk certainly indicate total blindness on the part of his pigeons, and he is of opinion that all those who have held that ablation of the cerebral hemispheres does not cause total blindness are in error, owing to the fact of the extirpation of the hemispheres not having been complete. Schrader, however,[15] describes the phenomena which he observed in two pigeons, from which, according to the *post-mortem* examination of von Recklinghausen, he had entirely removed every portion of the cerebral hemispheres. None of the cortex remained, but only minute remnants of the cut cerebral peduncles, which were, moreover, in a state of softening. These pigeons, within a few days after the operation, behaved in such a manner as can only be explained by their still retaining some form of vision. For they not only avoided obstacles in their path, or in their flight, but appeared able to fly from one place and alight securely on another. These flights were mostly, if not entirely, caused by conditions calculated to induce a change of position, such, for instance, as mounting them on a narrow basis of support, or putting them through balancing experiments. They never on any occasion spontaneously flew upwards from the ground.

With respect to the sense of hearing, Schrader verified in some of his animals the observations of Longet, that loud sounds, like the explosion of a percussion cap, caused a sudden start, but beyond this there were no signs of impressionability to auditory

[7] Physiologie des Froschgehirns, *Pflüger's Archiv für Physiologie*, 1887, Band 41.

[8] *Système Nerveux*, 1842.

[9] *Anatomie et Physiologie du Système Nerveux*, 1842.

[10] *Op. cit.*

[11] Observations and Experiments on the Corpora Striata and Cerebral Hemispheres of Pigeons, Royal Society, Edinburgh, 1873.

[12] Ueber die Bedeutung des Grosshirns, *Archiv. für Psychiatrie*, 1876.

[13] *Das Sehcentrum bei Fröschen*, Berlin, 1880.

[14] "Uber die centralen Organe für das Sehen und das Hören bei den Wirbelthieren; *Sitzungsberichte d. Berlin Akademie d. Wissenschaften*, July, 1883.

[15] Physiologie des Vogelgehirns, *Pflüger's Archiv*, Bd. 44.

stimuli. If the results described by Schrader are correct, and of this the description given by himself and von Recklinghausen seems to leave little room for doubt, we shall then be obliged to class birds with fishes and frogs, which without doubt retain their sense of sight, and guide their movements accordingly, notwithstanding the complete removal of their cerebral hemispheres.

Mammals.—While removal of the cerebral hemispheres (including corpora striata) in the lower vertebrates is compatible with survival for a considerable length of time, the case is different with mammals. In these the operation causes fatal shock, or is followed by secondary effects which result in speedy death. For this reason it has not been found possible to determine, as in the lower vertebrates, what functions, after considerable lapse of time, might still be exhibited by the lower centres in the entire absence of the higher. The mammals on which the operation has succeeded best have been chiefly of the lower orders, such as rabbits, guinea-pigs, and rats. When the hemispheres have been removed from a rabbit or a guinea-pig, the animal, at first utterly prostrate, begins after a varying interval, say from half an hour or more, to exhibit a capacity for the performance of actions of a considerable degree of complexity. The muscular power of the limbs has, however, become enfeebled to a noteworthy extent, and, relatively, much more so in the fore than in the hind limbs. It is, nevertheless, able to maintain its equilibrium, but sits huddled up, while the legs tend to sprawl, or are planted in unnatural positions. It resists attempts to overthrow its balance, and if disturbed regains its former attitude. If the foot or tail be pinched, the animal will bound forward in its characteristic mode of progression, and again settle down when the effect of the stimulus has worn off. It may shake its ears, slightly change its position, rub its snout with its paws, or scratch its body, and again subside into a condition of perfect quiescence. The pupils contract when a light is thrown into the eye, and the eyelids wink when the conjunctiva is touched. Loud sounds will cause the ears to twitch, or provoke a sudden start. According to Longet, colocynth placed in the mouth will cause movements of the tongue and organs of mastication, in all respects resembling those of disgust, and efforts to get rid of the nauseous taste. Ammonia held before the nostrils will cause a sudden retraction of the head, or induce the animal to rub its nostrils with its paws. Not merely does it respond by movements to a pinch or prick of its foot or tail, but, if the stimulation be more severe, it will utter repeated and prolonged cries of a plaintive character. All spontaneity seems to be abolished; but it is usual for the animals, after the period of quiescence has passed, to make apparently spontaneous running movements, which, however, are found to depend upon irritation caused by the secondary changes set up in the wound.

Whether after removal of the cerebral hemispheres rabbits and other rodents can see, is a question which has been the subject of lively controversy between Christiani and Munk.[16] Christiani, after careful severance of the hemispheres and corpora striata immediately anterior to the optic thalami, states that he has seen rabbits pass and repass obstacles such as legs of chairs and tables, and is of opinion that, though they do not see like normal rabbits, they are still able to guide their movements in accordance with retinal impressions. Munk, on the other hand, denies the accuracy of Christiani's experiments, and holds that rabbits, after removal of the cerebral hemispheres, are absolutely blind, and show no indications whatever that they are influenced by light, except as regards the contraction and dilatation of the pupils. He believes that the apparent avoidance of obstacles by Christiani's rabbits was a pure accident, as the obstacles did not happen to lie in their path.

The question is one which cannot be said to be definitely settled, though the facts mentioned in respect to fishes, frogs, and birds would incline one to believe that Christiani's results and conclusions may have a solid foundation. On this point, however, and on others relating to the sensory and motor faculties of brainless mammals it is difficult to arrive at altogether satisfactory conclusions, as they, unlike the lower vertebrates, have as a rule so speedily succumbed to the operation. Hence the lower animals' centres have no time to recover from the shock which must necessarily ensue from such a violent rupture of the solidarity previously existing between them and the highest centres. As the cause of death in mammals seems largely dependent upon secondary (inflammatory and other) consequences, and not on the mere fact of removal of the hemispheres themselves, it is much to be desired that some method may be discovered whereby the animals may be maintained alive longer than has hitherto been found possible. The nearest approach to this has been attained by Goltz,[17] who has made a series of careful observations on dogs for prolonged periods, after very extensive destruction of both cerebral hemispheres. Though the destruction has been far from complete in any case, yet the phenomena described by him teach lessons of the utmost importance in the comparative physiology of the brain. Goltz himself has utilised these experiments as the bases of his polemic against cerebral localisation, but we may, for the time, abstract from their bearing in this direction, and consider the facts themselves which he has recorded.

Goltz[18] thus describes a dog in which he had by repeated operations destroyed a large extent of both hemispheres. The amount of primary destruction, together with the secondary atrophy so induced, was so great that the whole brain weighed only 13 drachms instead of 90, which should have been the weight of a normal brain in an animal of the same size. This dog had a profoundly demented, expressionless face. Left to itself it wandered about restlessly, paying no attention to what was going on around it. All its movements were awkward and unsteady, but it exhibited no complete paralysis. It slipped, however, on a smooth surface, and its legs tended to sprawl from under it, so that it would fall upon its abdomen. From this position it would recover itself and again begin its walk. It had the utmost difficulty in feeding itself, though it could find its food when placed in the customary corner of its cage, yet it seemed unable to find it when placed in an unusual position, and even when the food was brought directly under its nose it would snap aimlessly as often outside the dish as in it. It was utterly unable to use its paws for holding and gnawing a bone. It paid no attention to strangers, men or animals; did not wince at the brightest light suddenly thrown in its eyes, and exhibited no fear at any kind of threat. Though it appeared absolutely blind, yet numerous and varied experiments demonstrated that it was able to guide its movements by sight. It did not run against obstacles as it invariably did when its eyes were blindfolded. It was not deaf, for it could be waked out of sleep by a loud sound, but the character of the sound made no further impression upon it. It did not heed tobacco smoke or chloroform vapour, and would eat a piece of wood as readily as a bone. It did not appear to be influenced by the proximity of another dog. It exhibited no emotion of anger when another stole its food, nor did it express pleasure in the usual way by wagging its tail. Its cutaneous sensibility was everywhere diminished, but no part was absolutely without feeling. If its foot was severely pinched it would draw its leg back and bite angrily.

The symptoms exhibited by this dog and another similarly operated upon are thus summed up by Goltz: "Both animals were essentially only wandering, eating, and drinking reflex machines. Both were utterly indifferent to man and beast. Both had obtuseness of all their senses. Each had sensation in every part of its skin, and effected movements with all its muscles. Neither exhibited any expression of pleasure; on the other hand, both were easily roused to wrath. Both were profoundly demented."

The impairment of all the sensory and motor faculties in these and other dogs operated upon by Goltz—in which it is certain that not one of the specific centres was entirely destroyed—would without doubt have been more profound than in rabbits and guinea-pigs had it been possible to extirpate the hemispheres entirely. And when we come to consider the effects of partial cerebral lesions in man, we shall see reason for believing that if in him the whole of the hemispheres were removed, providing this were compatible with life, there would be such complete and enduring paralysis of motion, and annihilation of all the forms of sense, that scarcely a trace would remain to those responsive and adaptive reactions which survive the removal of the cerebral hemispheres in animals lower in the scale.

It thus appears that, notwithstanding the complete extirpation of the cerebral hemispheres, animals, in proportion to their lowness in the scale, besides duly retaining and regulating all their organic functions, remain possessed of varied powers which may be classed generally under the heads of equilibration, co-ordination of locomotion, emotional expression, and adaptive reactions in accordance with impressions made upon their organs of sense. These are organised in the mesencephalic and spinal centres in the highest degree in fishes, frogs, and pigeons; to a less degree in the lower mammals, and least of all in monkeys and man.

16 *Physiologie des Gehirnes*, 1885.

17 Verrichtungen des Grosshirns, *Pflüger's Archiv*, 1876-1888.

18 *Op. cit.*, p. 134.

I do not intend on the present occasion to enter on a consideration of the respective *rôles* of the spinal, cerebellar, and mesencephalic centres in the regulation of these different forms of activity. We may—practically in some and theoretically in all—separate the mesencephalon and spinal cord into a congeries of individual centres, each with its own afferent and efferent nerves, co-ordinating synergic movements, each in its own province, and all co-operating together harmoniously by means of commissural or intracentral fibres. The individual metameres form units in a complex whole, acted on by the nerves of special sense, and subordinate to the supreme nerve centres, through which the adaptation of the organism to its environment is effected. Nor will I enter on a discussion of the vexed question as to whether the actions of the lower centres are indicative or not of intelligence. Most of the differences on this point turn mainly on the meaning of terms. If, with Mr. Romanes, we regard fluctuating adaptation to external conditions as the criterion of intelligence, we shall certainly not be able to deny that the actions of the lower centres are indicative of intelligence in this sense. For the observations of Steiner, Schrader, and others on the lower vertebrates, show that forms of activity which we are accustomed to regard in man as exclusively cerebral, and indicative of conscious discrimination, are capable of being manifested by these animals in the entire absence of their cerebral hemispheres. Nor can we say that spontaneity, which we have also been accustomed to regard as conditioned by the cerebral hemispheres, is entirely abolished in brainless animals; for we see that, without any apparent change in external conditions, they move spontaneously, and comport themselves not unlike normal animals. We can, however, in most cases, if not in all, refer these so-called spontaneous movements to immediate ento- or epi-peripheral impressions; whereas, in normal animals, though their so-called spontaneity is primarily derived from a similar source, the connections are more remote and far more difficult to trace.

These and other similar facts lead to the conclusion that between the simplest reflex action and the highest act of intelligence there is no essential difference—each passing by insensible gradations into the other. We can infer only, we can prove nothing conclusively, regarding the existence of states of consciousness in others than ourselves, and less easily in the case of the lower animals than in man. But we are entitled to say that the activity of the lower centres does not affect the consciousness of the individual; for, when by lesion of the internal capsule the sensory tracts are cut off from their cortical connections, the individual has absolutely no consciousness of impressions made upon his organs of sense, so that we may conclude that, in man at least, states of consciousness are indissolubly connected with the activity of the cerebral hemispheres.

The results of ablation of the cerebral hemispheres indicate nothing for or against the doctrine of functional localisation, nor do the experiments of Goltz in the least degree militate against the existence of specific centres; for if, even after complete bilateral extirpation of these centres, the functions which survive do not transcend those capable of being manifested in the entire absence of the cerebral hemispheres, there still remains the question whether the lesions have not caused a loss or paralysis of something of a higher order. That this is so is capable of ample demonstration, of which not the least part has been contributed by the very facts which Goltz himself has ascertained through the numerous and varied devices which he has so ingeniously contrived. It is no explanation of the defects which admittedly result from removal of the cerebral hemispheres to say that they are caused by a loss of intelligence. This is merely restating the facts in a more metaphysical but less intelligible form. We are not, however, dealing with metaphysical terms when we are studying the effects of lesions of the cerebral cortex. We are dealing with material entities connected with sensory and motor tracts, and it is our object to determine, if possible, what are the anatomical and physiological factors which are co-related with the functions which we generalise under the head of intelligence; and there appears to be nothing which can *a priori* be urged against the notion that the various factors of intelligence have their substrata in definite regions specifically related to certain motor and sensory functions. Flourens, as is well known, denied every species of localisation in the cerebral hemispheres. To this conclusion he appears to have been led not more by his own experiments than by the prevalent conceptions as to the unity and indivisibility of the mind, and as a reaction against the organology of Gall and his followers. To Gall, however, let us in passing pay the tribute that in his analysis he followed strictly inductive methods, and made many observations of enduring value; though his synthesis of the brain as a congeries of separate organs, each autonomous in its own sphere, and all mysteriously inherent in some unifying, immaterial substratum, has failed to commend itself to the scientific world. Flourens thus sums up his conclusions:—

"Thus one may remove, anteriorly, or posteriorly, from above, or from the side, a considerable portion of the cerebral lobes without destroying their functions. Even a small portion of these lobes, therefore, suffices for the exercise of their functions. In proportion to the extent of the removal, all the functions become impaired, and gradually fail; and beyond certain limits they are altogether annihilated. The cerebral lobes, therefore, co-operate as a whole in the full and complete exercise of their functions. Finally, when one form of perception is lost, all are lost; when one faculty disappears, all disappear. There are, therefore, no special seats either of special faculties or special perceptions. The faculty of perceiving, judging, and willing one thing resides in the same region as that of perceiving, judging, and willing another; consequently, this faculty, essentially one, resides essentially in one organ."[19]

Though the doctrines of Flourens met with general acceptation, they were contested on experimental grounds by some physiologists, more particularly by Bouillaud.[20] The experiments of Bouillaud on pigeons, dogs, and rabbits led him to conclude that destruction of the anterior lobes alone caused symptoms of profound dementia. Though the animals were able to feel, see, hear, smell, and to execute a number of spontaneous and instinctive movements, they were unable to recognise their relations to the objects by which they were surrounded. They were unable to feed themselves, and had in general lost all reasoning powers. An animal, said he, in which the anterior lobes have been destroyed, "though deprived of the exercise of a more or less considerable number of intellectual acts, continues to enjoy its sensory faculties; a proof that 'sensation' and 'intellection' are not one and the same function, and that they have separate localities." Bouillaud's results have, I think, received confirmation and elucidation from my own experiments on monkeys, as well as those of Goltz and Schrader on dogs and pigeons. Bouillaud, however, did not consider that his own experiments had done more than merely raise the question of localisation, and it was generally believed that, so far at least as experimental data were concerned, the doctrine of specific localisation had no secure basis of support. From the clinical standpoint, however, facts were continually being presented which seemed altogether unintelligible except on some theory of localisation; and clinical observers, such as Bouillaud himself, Andral, and others, wisely suspended their judgment until further facts should be brought to light, which might serve to explain the apparent irreconcilable discrepancy between human pathology and experimental physiology.

Bouillaud[21] recorded certain clinical facts which seemed to indicate a connection between lesions of the anterior lobes and loss of speech, thus affording some confirmation of the theories of Gall on the subject. Dax (1836) established the special relation of aphasia to right hemiplegia and lesions of the left hemisphere; but the connection between aphemia, or aphasia, and lesion more particularly of a definite region of the left hemisphere, namely, the base of the third frontal convolution, was first pointed out by Broca (1861). Broca's observations have since been amply confirmed by clinical and pathological research, and further elucidated by physiological experiment.

The next great advance in cerebral localisation was made by Hughlings Jackson (1861),[22] who, from a study of the forms of epilepsy, now appropriately known by his name, furnished cogent reasons for believing that certain convolutions near, and functionally related to, the corpus striatum had a direct motor signification. By irritation or "discharging lesions" of these convolutions, localised, or general unilateral convulsions of the opposite side of the body were induced. Owing, however, to the fact, as Hughlings Jackson has remarked, that "the damage by disease is often coarse, ill-defined, and widespread," the determination of the functions of the brain by the clinico-pathological method had made comparatively little progress, there being apparently no constant uniformity between the seat of the disease and the sym-

[19] *Op. cit.*, p. 99.

[20] "Rech. Exp rim. sur les Fonctions du Cerveau, et sur celles de sa Portion antérieure en particulier." *Journ. de Physiol. Expérim.*, 1830, T. x, p. 91.

[21] *Archives de Médecine*, 1825.

[22] *Clinical and Pathological Researches on the Nervous System.*

ptoms manifested. The difficulty of discriminating between the direct and indirect effects of cerebral lesions has furnished Brown-Séquard[23] with arguments in favour of his peculiar views, that all the symptoms of cerebral disease are due to some dynamic influence exercised by the lesion on parts situated at a distance (and always apparently out of reach), which are credited with the functions lost or otherwise disturbed.

A glance at the accompanying diagram (Fig. 2) founded by Exner[24] on the examination of a number of cases of lesion of the left hemisphere will show you the extraordinary diversity in position of those accompanied by practically the same symptom. It will be seen, for instance, that though the lesions which cause affection of the upper extremity are mostly grouped in a certain region, yet there is scarcely a point on the convexity of the hemisphere lesion of which has not caused a similar result. These and such like are the data on which Exner has founded his theory of *absolute* and *relative* centres; absolute centres being those destruction of which invariably, relative centres being those destruction of which only frequently, induces the same symptom. The distinction appears to me to have no valid foundation. Mere frequency is not a sufficient basis on which to found causal relationship. For, if the so-called relative centres can be, and have been times out of number, destroyed without any disturbance of the function with which they are supposed to be related, and if the said function can be annihilated while the relative centres are intact, it is obvious that the relationship is nothing more than mere coincidence or juxtaposition.

The whole aspect of cerebral physiology and pathology was revolutionised by the discovery, first made by Fritsch and Hitzig in 1870,[25] that certain definite movements could be excited by the direct application of electrical stimulation to definite regions of the cortex cerebri in dogs. As these experiments are now of historic interest, I extract the accompanying figure (Fig. 3) and the description, in their own words, of the facts which they had at that time ascertained.

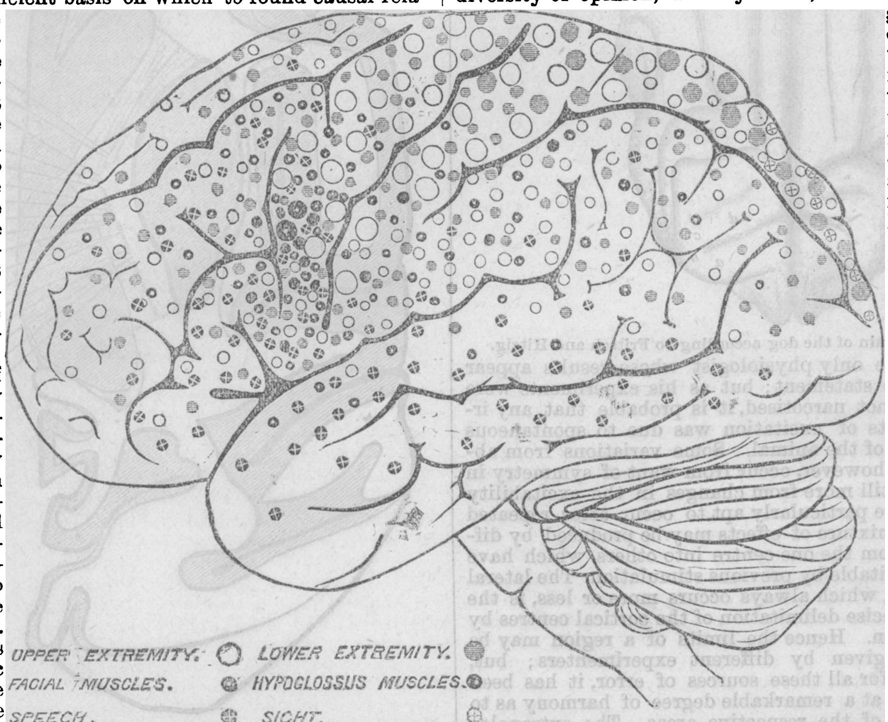

Fig. 2.—After Exner's Tafel xxv. The diagram is marked with larger and smaller circles of the same order. The larger circles indicate the absolute centres, the smaller the relative centres. The intensity of the latter is indicated by the closeness of the circles to each other.

"The centre for the neck-muscles (Fig 3 *a*) lies in the lateral part of the prefrontal gyrus at the point where the surface of this convolution abruptly descends. The outermost extremity of the postfrontal gyrus contains, in the neighbourhood of the lateral end of the frontal fissure (Fig. 3 *b*) the centre for the extensors and abductors of the fore limb." Somewhat behind the same, and nearer the coronal fissure (Fig. 3 *c*) lie the ruling centres for the flexion and rotation of the limb. The centre for the hind leg (Fig. 3 *d*) is also found in the postfrontal gyrus, but nearer the middle line than that of the fore leg, and somewhat further back. The facial (Fig. 3 *e*) is innervated from the middle part of the super-Sylvian gyrus. This region generally has an extension of over 0.5 centimètre, and stretches before and behind the bend over the Sylvian fissure. We must add that we did not always succeed in getting the neck-muscles in action from the first mentioned point. The muscles of the back, tail, and abdomen we have often enough excited to contraction from points lying between those marked, but no circumscribed point from which they could be individually stimulated could be satisfactorily determined. The whole of the convexity lying behind the facial centre we found absolutely unexcitable, even with altogether disproportionate intensity of current."

The subject of the electrical excitability of the cortex and its signification was next taken up by myself in 1873,[26] more particularly with the object of putting to experimental proof the views of Hughlings Jackson in reference to the causation of unilateral epileptiform convulsions. While amply confirming these doctrines in all essential particulars, my attention became specially directed to the question of definite localisation, and I was led minutely to explore, not only the hemispheres of dogs, but also those of monkeys and various other orders of vertebrates. Similar researches have been undertaken and published in almost every country, and by experimenters too numerous to mention, but nowhere with greater care and detail than by Beevor, Horsley, and Schäfer[27] in our own. The facts revealed by electrical exploration of the hemispheres have been, and still are, the subject of considerable diversity of opinion, and by some, as Brown-Séquard,[28] are regarded as of no greater significance than the contortions which may be induced by tickling the sole of the foot. There cannot, however, be a doubt that from them, and the further experiments to which they have pointed the way, has sprung the whole modern doctrine of exact cerebral localisation.

Before discussing the different specific reactions and their functional significance, it will be desirable to enter on a brief consideration of the characters and conditions of the excitability of the cerebral cortex.

In normal states the grey matter of the cortex is entirely or almost entirely, insensible to mechanical stimulation. Luciani, however, states that though the convexity of the hemisphere does not react to this form of stimulation, yet he has been able to produce movements of the opposite limbs by irritation of the walls of the crucial sulcus. Couty[29] also states that he has found the convolutions mechanically excitable after ligature of the cerebral arteries. Whether we accept these statements as being strictly accurate or not, it is certain, as was shown by Franck and Pitres,[30] that when the cortex has become inflamed and congested by exposure or traumatic lesion, it becomes irritable to mechanical stimulation, and may respond not merely by partial movements of the opposite limbs, but also by a unilateral epileptic fit. This is, in fact, the experimental induction of the discharging lesions described by Hughlings Jackson. It is also held by some—for example, Landois[31]—that the cortex is chemically excitable: a fact, however, which may be due to the inflammatory condition of the tissues thereby induced. The most effective excitant is the application, by closely approximated electrodes, of a galvanic or

23 Physiological Pathology of the Brain, *Lancet*, 1876, and *Archives de Physiologie*, 1877-1890.
24 *Localisation der Functionen in der Grosshirnrinde des Menschen*, 1881.
25 *Reichert, u. Du Bois-Reymond's Archiv*, 1870, Heft 3.

26 Experimental Researches in Cerebral Physiology and Pathology, *West Riding Lunatic Asylum Reports*, vol. iii, 1873.
27 *Phil. Trans.*, 1888.
28 *Archives de Physiologie*, January, 1890.
29 *Comptes Rendus*, March, 1879.
30 *Archives de Physiologie*, 1883.
31 Abstract in *Neurolog. Centralblatt*, 1890, p. 145.

faradic current of moderate intensity. Fritsch and Hitzig, in their researches, employed the former, but preference has generally been given by other experimenters to the faradic current as being the best calculated to elicit the characteristic reactions of the cortical centres. When an animal is sufficiently narcotised to abolish all restless or spontaneous movements—and the anæsthesia must not be too profound, otherwise all reactions cease—the application of the electrodes to different regions calls forth definite motor reactions with such uniformity that, when once the limits of the said region have been accurately defined, one may confidently predict the exact movement which will occur in animals of the same species. This is a fact which is beyond all dispute, and has been frequently demonstrated by myself, Horsley, and others, and, indeed, may be regarded as an ordinary lecture experiment.

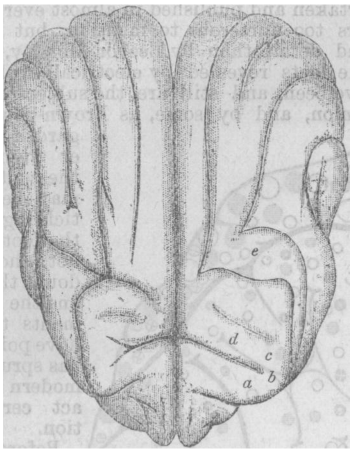

Fig. 3.—Centres of the brain of the dog according to Fritsch and Hitzig.

Couty[32] is perhaps the only physiologist whose results appear to contradict the above statement; but as his experiments were performed on animals not narcotised, it is probable that any irregularity in the effects of excitation was due to spontaneous movements on the part of the animal. Some variations from absolute uniformity may, however, occur from want of symmetry in the convolutions, and still more from changes in the excitability of the cortex. These are particularly apt to occur after repeated exploration, so that a mixture of effects may be produced by diffusion of the current from the one centre into others which have been rendered hyperexcitable by previous stimulation. The lateral diffusion of the current, which always occurs more or less, is the chief obstacle to the precise delimitation of the cortical centres by the method of excitation. Hence the limits of a region may be somewhat differently given by different experimenters; but, making due allowance for all these sources of error, it has been found possible to arrive at a remarkable degree of harmony as to the locality and extent of the respective areas. The extrapolar diffusion of current which can be demonstrated in the brain, as in other animal tissues, has been regarded by Dupuy[33] as an insuperable objection to the theory that the results of application of the electrodes to the cortex are due to stimulation of the cortex itself; and attempts are made to explain them away by mere physical conduction of the currents to centres and tracts at the base of the brain. But no satisfactory explanation can thus be afforded of the manifest differences in reaction which follow the application of the electrodes to regions in close proximity to each other, nor of the total absence of reaction when the electrodes are placed on the island of Reil, which is nearer the base of the brain than other regions which act uniformly and without fail.

The chief objection to the direct excitability of the cortex itself is found in the fact that, even after removal of the cortex, similar reactions are still obtainable when the electrodes are placed on the subjacent medullary fibres. This was first pointed out by Burdon-Sanderson,[34] and has been confirmed by all subsequent experimenters. After removal of the cortex, however, the medullary fibres lose their excitability, like motor nerves separated from the anterior cornua of the spinal cord, so that, after a lapse of four days, no reactions can be produced by the strongest stimulation. This fact completely disposes of the physical-conduction-to-the-base-of-the-brain hypothesis. It has thus been satisfactorily established that the cones of medullary fibres, corresponding to the respective cortical centres, are functionally differentiated like the cortical centres themselves, and, as has been shown by Franck and Pitres,[35] and more recently, with greater detail, by Beevor and Horsley,[36] maintain their individuality, and are echeloned in definite and regular order in the internal capsule.

On the accompanying figure (Fig. 4), kindly supplied me by

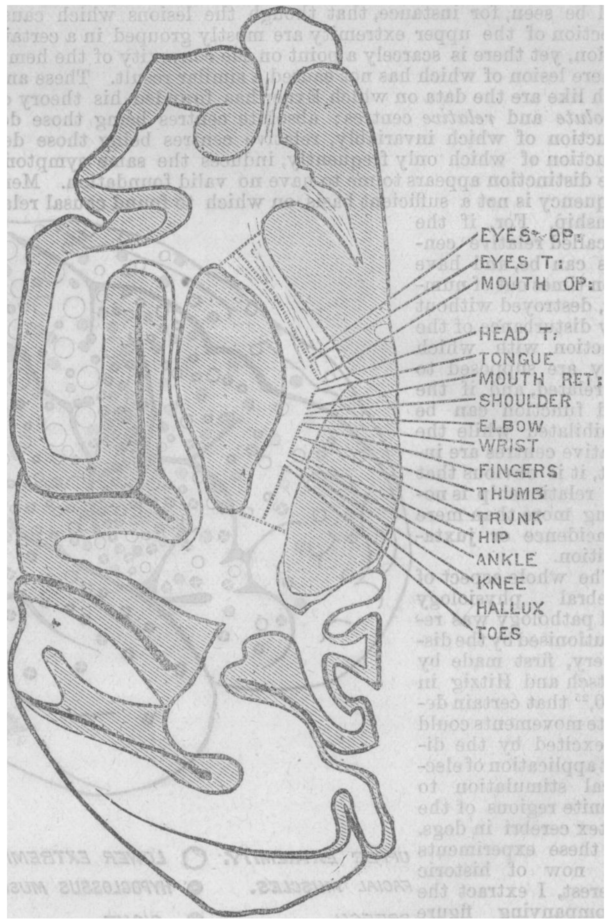

Fig. 4.—Arrangement of the motor fibres of the internal capsule, according to Beevor and Horsley.

Dr. Beevor, are marked the points on the internal capsule from which, according to their recent researches, minimal stimulation excites the respective movements which are indicated on the margin. But it does not follow, because the medullary fibres are excitable, that the corresponding cortical regions are unexcitable, and that the current merely passes through them. It is *a priori* more likely that there is also functional differentiation of the cortical centres to which they are distributed, and that the grey matter is, under normal conditions, the natural excitant of the reactions which we are able to produce by artificial stimulation with the electric current. And a comparison of the respective reactions of the cortex and medullary fibres indicates such differences as can only be explained on the supposition that the cortical centres are themselves excitable.

First, as regards the relative excitability of grey matter and subjacent medullary fibres. This is a point on which there are some differences of opinion, but Putnam found[37] the medullary fibres less excitable than the cortex, so that in order to produce the customary reaction, it was necessary to use a much stronger

[32] Le Cerveau Moteur, *Archives de Physiologie*, 1883.
[33] *Examen de quelques Points de la Physiologie du Cerveau*, 1873.
[34] *Proceedings Royal Society*, June, 1874.
[35] *Comptes Rendus de la Société Biolog.*, 1877.
[36] *Proceedings Royal Society*, No. 286, 1890.
[37] *Boston Med. and Surg. Journal*, 1874.

current than before. This has been confirmed by Franck and Pitres, who have further shown that the diminished excitability cannot be accounted for by mere shock or hæmorrhage, inasmuch as the neighbouring grey matter acted as readily as before. They have further given reasons for believing that the contrary results obtained by Richet,[38] and Bubnoff and Heidenhain[39] are due to the action on the cortex of the chloral and morphine under which their experiments were performed. These agents, without doubt, paralyse the excitability of the grey matter, It was noted by Fritsch and Hitzig, in their experiments, that the anodal closure was a more effective stimulus than the cathodal—a fact which might be interpreted as signifying that the real stimulus proceeded from the virtual cathode in the deeper layers of the cortex, or termination of the medullary fibres. This, however, has been shown by Gerber,[40] not to be uniformly the case. Gerber finds that when the cortex is in a normal state the cathode is the more effective stimulant, but that when changes have occurred from long exposure the anode predominates. These experiments would, therefore, indicate that in the normal condition of the brain the laws of galvanic excitability are the same as for motor nerves.

Another important difference between the reactions of the cortex and the subjacent medullary fibres, which was first pointed out by Franck and Pitres, is that the time lost between the application of the stimulus and the occurrence of muscular contraction is much greater in the case of the former than the latter. This interval, after deducting the time necessary for the transmission of the impulse through the spinal cord and motor nerves, indicates a retardation in the cortex of 0.045 second. After removal of the grey matter and application of the electrodes to the medullary fibres, the period of retardation diminishes to 0.030 second, that is, about one-third less, and this difference is put at a considerably higher figure by Bubnoff and Heidenhain.

The signification of this fact is that the grey matter of the cortex does not behave like an inert layer, which merely allows transmission of the electric current to the medullary fibres, but, like other nerve centres, stores up and transforms the stimuli which it has received into its own energy.

There is also a characteristic difference between the muscular curves registered on stimulation of the cortex and medullary fibres respectively. In the latter case the curve rises abruptly, and is of short duration; while in the former it rises more gradually, is more prolonged, and frequently marked by the occurrence of a secondary tetanus, which latter is altogether peculiar to the cortex, and is never seen when the medullary fibres alone are stimulated. The cortex is apt, after repeated stimulation, or after the receipt of a succession of stimuli, each insufficient to produce reaction, to respond by tonic, followed by clonic, spasms of the correlated muscles of a truly epileptic type. These convulsions tend to spread and become generalised in the order and sequence originally described by Hughlings Jackson. They never occur on stimulation of the medullary fibres alone, apart from the intervention of the grey matter of the cortex on the one side or the other, and cannot be produced if the cortical centres are entirely destroyed on both sides. The duration of the effects of stimulation of the medullary fibres is strictly proportional to that of the stimulus which is applied to them. We shall also see as we proceed that the effects of localised destruction of the cortex are the counterpart of those of irritation, however induced, and we may from this conclude that there is the same functional differentiation in the cortex as in the medullary fibres, even if the facts which I have just mentioned should not be regarded as of themselves completely establishing this proposition.

38 *Sur les Circonvolutions Cerebrales*, 1879.
39 *Pflüger's Archiv. f. Physiologie*, 1881.
40 "Beiträge zur Lehre von der electrischen Reizung des Grosshirns," *Pflüger's Archiv für Physiologie*, Band 39, 1888.

Whooping-Cough in Paris.—At a recent meeting of the Council of Hygiene of the Department of the Seine, a report was presented by M. Ollivier which showed that 520 children had died of whooping-cough in Paris during 1889. Of these, 13 were aged less than one month, 207 between one month and a year, 142 between one and two years, 142 between two and five, and 16 between five and ten years. The Council passed a resolution that the disease should be looked upon as a very serious illness in children under two years of age, and that cases should be isolated for at least fifteen days after the disappearance of the whoop, or, if possible, till the cough has finally ceased.

A CASE OF GASTROSTOMY.

By A. W. MAYO ROBSON, F.R.C.S.,
Honorary Surgeon, Leeds General Infirmary; Honorary Consulting Surgeon, Batley Hospital; Lecturer on Practical Surgery, Yorkshire College; and Examiner in the Victoria University.

Although gastrostomy for non-malignant obstruction is a fairly successful operation, when performed for cancer of the œsophagus it is one of extreme fatality. Any means, therefore, which will help to reduce the mortality may be worth recording.

The patient whose case is related below was operated on by a method first suggested by Mr. Greig Smith, and described by him in his work on *Abdominal Surgery*. After the operation the patient lived in a state of comparative comfort for eleven months, during the whole of which time he never took a particle of food except through the artificial opening into the stomach. By this method of suture the peritoneal coat of the stomach is kept in apposition with the parietal peritoneum in a continuous circle for some distance from the point where the stomach is to be opened. The insertion of two loops of silver wire, as suggested by Mr. Bryant, serves to mark the spot at which the stomach is to be opened, and by means of these wires the stomach can be manipulated whilst the silk suture is being applied. With a round needle threaded with from 12 to 15 inches of moderately thick silk, a continuous suture is passed in the anterior wall of the stomach, in a circle of about 2 inches in diameter under the peritoneal coat, taking up a little of the muscular layer as well, the suture being made to emerge and leave a loop at every three-quarters of an inch of the circle, thus leaving about six loops protruding from the serous surface of the stomach. (Fig. 1).

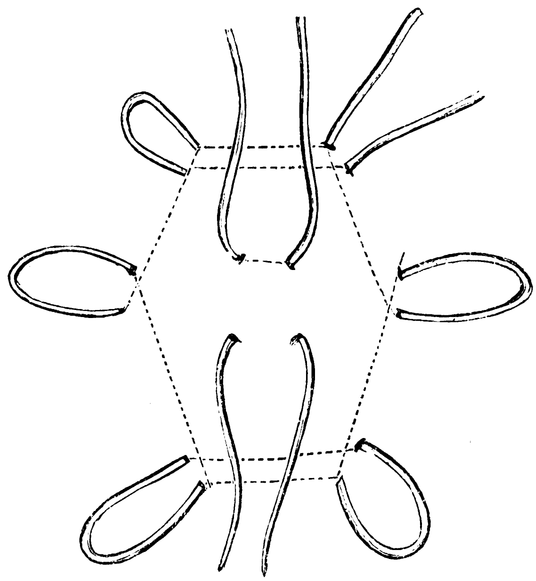

Fig. 1.

At corresponding situations on the skin, about half an inch from the edge of the wound, a handled needle with a hooked eye is pushed through all the layers of the abdominal walls, catches up the loops, and brings them to the surface of the abdomen one after another. As each loop is drawn up a piece of elastic tubing or a piece of catheter is slipped into it. The loops are then moderately tightened over the catheter by pulling at the ends of the silk. Finally, the ends of the silver suture are hooked under the catheter, serving to keep the exposed parts well up in the gaping wound. (Fig. 2). It will thus be seen that by this method of fixing the stomach accurate peritoneal apposition is obtained over a large space, and the stomach is not dragged out too far, thus lessening the risk of a dribbling fistula. Moreover, the method is rapidly and easily carried out.

History of the Case.[1]—T. O., aged 51, admitted to the Leeds In-

1 Notes furnished by my house-surgeon, Mr. Frank Hudson.