REMARKS
ON
THE RELATIONS OF DIFFERENT DIVISIONS OF THE CENTRAL NERVOUS SYSTEM TO ONE ANOTHER AND TO PARTS OF THE BODY.

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[AFTER expressing his inability properly to thank the Society for asking him to deliver this Lecture, and after remarking on the study of nervous maladies as Dissolutions, Dr. Hughlings Jackson said:]

For the kind of work indicated some scheme of the whole nervous system is necessary. A morphological one, such as spinal cord and encephalon, or such as cord, medulla, pons, cerebellum and cerebral hemispheres, will not serve us. We must have one after degrees of directness and complexity with which nervous centres, or, as I shall say, Levels, represent impressions and movements of parts of the body; this is an anatomical not merely a morphological scheme.

I divide the central nervous system into two Sub-systems—Cerebral and Cerebellar. The two have what I call the Lowest Level in common, or in other words that level is the lowest level of the cerebral sub-system and of the cerebellar sub-system.

The Lowest Level extends, it is suggested, from the tuber cinereum to the conus medullaris; it is made up of sensory and motor centres of the cord, medulla, pons, and aqueduct—representing the body in detail; motorily from ocular muscles (ciliary muscles?) to muscles of the perineum (sphincter ani?)—with the fibres inter-connecting these centres. There are also Superior Centres of the level itself; for example, there is the respiratory, medulla, centre, which represents movements of the respiratory apparatus indirectly—represents them by intermediation of the laryngeal, phrenic and costal motor centres of the level. There are, I submit, other Superior centres with their subordinate centres, for intestinal action, defæcation, micturition, the sexual act, parturition, etc.

The Rolandic region of the cortex cerebri and the prefrontal lobe are the motor provinces of, respectively, the middle and highest levels. As to the sensory provinces I have formerly spoken of the occipital lobes as the highest sensory centres of the cerebral sub-system, but I now find it difficult to conclude with any confidence as to what are the sensory provinces of the middle and highest levels of this sub-system. In what follows it is to be understood that the unit of constitution of the whole nervous system (not excluding the highest level, the so-called "mental centres") is sensori-motor; and also that, in the middle and highest levels at least, the so-called motor provinces are only *chiefly motor* and the sensory provinces only *chiefly sensory*. I have not attempted any division of the cerebellum into levels.

I admit that the scheme of three levels is incomplete; nothing has been said of the sympathetic nervous system, nor of what may be called the olfactory and optic nervous systems; the retina is developmentally part of the brain itself, and possibly some elements, or some layer, of the retina may be the lowest centre of the optic nervous system.

With regard to the lowest level, we have to consider its Intrinsic and also what I may call its Extrinsic elements. The intrinsic elements are, as aforesaid, the centres of the cord, medulla, pons, and aqueduct with their interconnecting fibres; what I have called Superior centres are also intrinsic elements of the level. The extrinsic elements are of two kinds: (1) fibres extrinsic upwards—for instance, those of the pyramidal tract; and (2) fibres extrinsic downwards—for instance, those of the posterior columns. The best illustration of extrinsic elements of the lowest level is given by a consideration of what Sir William Gowers has called ataxic paraplegia. The disease in this malady is of fibres of the lateral columns, fibres extrinsic upwards, and also of fibres of the posterior columns, fibres extrinsic downwards; although these fibres are solidly part of the morphological mass, the cord, they are no part of the lowest level; they are fibres connecting centres of that level with centres of the middle level and with parts of the body.

The next question is as to fibres extrinsic upwards connecting centres of the lowest level with the cerebellum. Connection by sensory fibres is admitted; connection by motor fibres is not generally admitted.

[Attention was then drawn to the very important and remarkable researches by Sherrington on Reciprocal Innervation and to some recent very valuable researches by Löwenthal. Löwenthal observed that when the cerebrum (of a dog) was removed, excitation of a certain part of the cerebellum, acting when the spinal cord was in tonus, produced relaxation of the triceps and contraction of the biceps. His experiments show a motor connection, if not a direct one of the cerebellum with anterior horns.]

I have now to restate an old hypothesis on dynamical relations of the two Sub systems by intermediation of motor centres of the lowest level. Speaking very roughly, and neglecting some parts of the body, the cerebellum represents movements of the skeletal muscles in the order trunk, leg, arm, preponderatingly extensor-wise; the cerebrum represents movements of the same muscles in the order arm, leg, trunk, preponderatingly flexor-wise. It is also supposed that impulses from motor centres of the higher levels of each sub-system continuously act upon the motor centres of the lowest level; that the impulses from each set of higher levels antagonise or inhibit one another in different degrees upon different lowest motor centres; that the degree with which the cerebral and the cerebellar impulses antagonise one another is the same as the order of the degree of their different representation of movements of muscles of the body. In accordance with this hypothesis the rigidity in the common cerebral paralysis, hemiplegia, results because cerebral influence being taken off the lowest motor centres as the cerebrum represents movements in the order arm, leg, trunk, cerebellar influence upon those lowest motor centres is no longer antagonised; there is cerebellar "influx" into the parts which the cerebrum *has abandoned*.

It was asserted against this hypothesis that upon complete transverse lesion of the spinal cord above the lumbar enlargement—both cerebral and cerebellar influence being excluded from motor centres below the lesion—the legs are rigid and the knee-jerks exaggerated. But a few years ago Dr. Charlton Bastian[1] brought forward cases showing that upon *total* transverse lesion of the spinal cord above the lumbar enlargement the legs are flaccid and the knee-jerks absent. His conclusions are, I think, adopted by most neurologists in this country; they have been confirmed by Bowlby, Thorburn, and Bruns (of Hanover). I have several times stated the objections which may be brought against the theory of cerebral and cerebellar influx, some of which I admit to be serious.

There is another way of considering the hypothesis of relations of the cerebral and cerebellar sub-systems to one another by their having the lowest level in common; we may compare and contrast certain cerebral and certain cerebellar maladies with one another as being Complementary Inverses (corresponding opposites). The best marked Complementary Inverse is a case of extensive cerebellar paralysis (trunk, legs, arms) and rigidity as the corresponding opposite of the double hemiplegia (arms, legs, trunk) and rigidity of an advanced case of paralysis agitans; in the former the attitude is opisthotonic, in the latter slightly emprosthotonic. There is another very important Complementary Inverse; in some cases of tumour of the middle lobe of the cerebellum there are tetanus-like seizures. They, being paroxysmal, are obviously of different nature from the persisting cerebellar paralysis with rigidity just mentioned as certainly as an epileptiform paroxysm (I mean the epilepsy described by Bravais, 1827) is of different nature from hemiplegia with rigidity. These tetanus-like seizures depend, I suppose, on *occasional* excessive discharges beginning in some part of the cerebellum; such paroxysms are, speaking generally, the Complementary Inverse of epileptiform or epileptic seizures from sudden *occasional* excessive discharges beginning in a part of the cerebral cortex. I used to think that drawing back of the neck was especially a cerebellar symptom. Dr. Buzzard[2] has, however, published a case of retraction of the head from tumour of one temporo-

sphenoidal lobe. Tetanus-like seizures occur in cases of glioma of the pons. I have pointed out that when there is cerebellar tumour such seizures may be said to be owing to pressure on the adjacent corpora quadrigemina or subjacent medulla. Those who adopt the pressure hypothesis have, in some cases of tumour of the middle lobe of the cerebellum, three things to account for: (1) cerebellar paralysis, (2) cerebellar paralysis with rigidity, and (3) tetanus-like seizures.

One important matter as to the relations of the several levels of the cerebral sub-system to one another is as to the degree with which the organs of the digestive, circulatory, respiratory, and thermal system are represented by the lowest level and higher levels. I submit that these organs, neglecting, however, those of the thermal system, as they serve in what I call the Menial work of digesting food, circulating blood, and aërating blood, are efficiently, are almost solely, represented by the lowest level; but as the manifestations during emotions show they are largely represented in other ways in the highest level. An illustration may make my meaning clearer; it is unlikely that the heart, to take very arbitrarily but a part of the circulatory apparatus, is represented positively in the higher levels in its character as a machine for circulating the blood (as a blood pump); but it is popular doctrine that the heart is engaged in manifestations during strong emotions and this means that it is represented in the highest level, that is, in the anatomical substrata of states of consciousness. I will further illustrate by the respiratory system; I confess that I do not think I could with any definiteness illustrate by the other systems.

The respiratory apparatus is engaged in three different operations; as only one of them is respiration proper, I shall use the term thoracic cage, or, briefly, cage, instead of respiratory apparatus: 1. There is respiration proper, organic duty, or menial work. 2. The cage serves in "voluntary" operations, as in drawing in the breath when told and whilst (fixation of the chest in "effort") lifting a heavy weight with one hand. 3. It is engaged during great emotions. The services 2 and 3 are animal or personal services in which the higher levels are concerned; they are not respiratory operations, they are not organic duties or menial work. (In these remarks I ignore the sensory elements necessarily engaged with motor elements in all operations.) I will make some further remarks on the differences between the first, respiratory, and the second, "voluntary" service of the cage. I have recorded[3] a case I saw with Mr. Wilkin that of a man who had, as we thought, "latent" pneumonia (knee-jerks absent). The thing I wish to make prominent is that during the patient's respiration proper, first service of his thoracic cage, the intercostal muscles did not act at all (his breathing was solely diaphragmatic) whilst these muscles acted perfectly in the "voluntary" operation, one of higher level initiation, of drawing in his breath when told (so-called "forced inspiration") second service of the cage; Dr. Barlow subsequently saw the patient with us and confirmed this double observation. (The patient recovered, his respiratory movements became normal and his knee-jerks returned). This case seems to me to demonstrate that the two services, 1 and 2, of the cage, are of very different origination. It is the only case of the kind I have seen, nor have I heard of any other like it.

One very important thing with regard to my subject is Regulation of the digestive, circulatory and respiratory systems. There are, I have put it, three factors in Regulation. Thus with regard to the respiratory system, there is (1) Nervous regulation; the respiratory, medulla, centre is probably to some extent automatic, goes on by itself; it is also influenced by impulses ascending the vagi and by the higher levels (by "upper brain tracts"). (2) There is mechanical regulation; the elasticity of the lungs and of the costal cartilages (expiration in quiet breathing being chiefly recoil). (3) There is what, for want of a better term, I will call the factor Chemical Stimuli; in the case I am dealing with by venous blood, a natural stimulus of the respiratory centre (deficiency of oxygen). With regard to chemical stimuli, a very bad term I admit, I have suggested that effete nitrogenous products act as natural stimuli to the vaso-constrictor, medulla, centre before they are eliminated by the kidneys. I have heard more than one medical man say that he felt better when a little gouty, better for mental exertion I suppose was meant. The late Milner Fothergill[4] said that "gout poison stimulates the intellect in the earlier stages of Bright's disease." I suppose that owing to an excess of nitrogenous effetes, to an excess of a natural stimulant, the vaso-constrictor centre is highly stimulated in certain cases of Bright's malady, whereby general arterial tension is raised; and since the cerebral arteries have comparatively little muscular tissue (some physiologists consider it not demonstrated that these arteries have vaso-constrictor nerves) the result will be that the brain gets more blood and thus in the early stages of the malady it will be, at least in some ways, in better working order. This state of things is, however, more pleasant than safe and yet a salutary reduction of high arterial tension by dieting and by medicine is not always appreciated by our patients. Schäfer's researches on the suprarenal capsules, his showing that an extract of the medulla of these bodies raises arterial tension, is very important in this connection; arterial tension is raised by this extract, by its action on the muscular coats of the arteries. (It is possible that effete nitrogenous products act similarly and not on the vaso-constrictor centre as I suggested.)

It will be seen that in speaking of regulation and in particular of the factor chemical stimulus I have not been leaving the topic of the lecture; for example, stimulation of the vaso-constrictor centre will influence the higher levels of the cerebral sub-system; there is a roundabout relation between the lowest level and these higher levels; from high tension the brain will get more blood, from low tension less. Broadbent has drawn attention to the influence of states of arterial tension in cases of epilepsy. In my opinion epilepsy (the so-called idiopathic) is owing to a discharge-lesion made up of a few cells of some part of the highest level (of one half of the brain). When arterial tension is high the cells of the discharge-lesion will with the rest of the brain, get more blood and they will be in consequence more nourished and will thus become more highly unstable; when arterial tension is low these cells will get less blood. The beneficial effects of nitroglycerine in some cases of epilepsy are probably owing to its lowering arterial tension; in the same way we may perhaps interpret the cessation of epileptic fits during febrile ailments and the good effects of an old-fashioned remedy, a seton; a miniature febrile condition being probably induced by that minor surgical operation.

I have spoken of the possible "stimulation of the intellect," to use Fothergill's expression, in some cases of raised arterial tension. There is, I think, another way in which "the intellect" is affected in certain abnormal states. It has been suggested by Greg (whom Fothergill quotes, *op. cit.*) in his *Enigmas of Life*, that bodily pain and disease "may directly contribute to the loftiest efforts of the intellect. They sometimes positively enhance its powers." Here is a very important question, too large a one to be dealt with fully here.

I spoke of venous blood as a "natural stimulant" of the respiratory, medulla, centre; it stimulates other centres of the lowest level. I have thought that very great supervenosity, as in severe cases of emphysema with bronchitis, annuls the function of the lumbar centres concerned with the knee-jerk Risien Russell finds that asphyxia first exaggerates, and then causes loss of, the knee-jerks in dogs. As to another level; in asphyxia there is loss of electrical excitability of the Rolandic area of the cortex (motor province of the middle level of the cerebral sub-system) in dogs; a very important matter with regard to the first division of what I call Lowest Level Fits. In some cases of supervenosis, there is delirium; the positive mental symptoms are not directly, but indirectly consequent, I submit, on the action of the supervenous blood; they do not, I think, signify that supervenous blood "excites the brain"; there is, I submit, greater activity in lower nervous arrangements of the highest level consequent on loss of function of the highest caused by supervenous blood—overaction of the lower from loss of control by the functionless highest. Consideration of the action of venous blood leads me to my next topic.

The Scale of Fits.—There are, I think, Lowest Level Fits, Middle Level Fits, (the epilepsy described by Bravais in 1827) and Highest Level Fits (so-called idiopathic epilepsy).[5]

I now consider only Lowest level fits and only those of these which I think are respiratory; other lowest level fits are pro-

ducible by certain poisons, by camphor and absinthe for example, and I think by some home-made poisons as in uræmic fits; there is still another group of lowest level fits analogous to those producible in guinea-pigs by Brown-Séquard's method.

It is certain that there are respiratory fits in some lower vertebrates, or rather, such fits are easily producible in them by experiment. Kussmaul-Tenner fits in rabbits are of this kind; whether these fits are produced by ligaturing the great arteries of the neck, by rapid bleeding or by sudden obstruction of the trachea, they depend on absence of oxygen; in each there is an excessive discharge beginning in the respiratory, medulla, centre. I have suggested[6] that laryngismus stridulus in man (the infant human being)[7] and convulsions in some cases of whooping-cough, are fits beginning by excessive discharge of the respiratory centre.

I must here point out that Horsley and Semon think that attacks of laryngismus stridulus are of cortical origin; they have shown that discharge of the laryngeal centre of one-half of the brain will close the glottis; they adduce the existence of carpopedal contractions in laryngismus stridulus as evidence favouring their view of its cortical origin. With great respect for the opinions of these men who have done such highly original work on laryngeal representation by the central nervous system, I think carpopedal contractions and paroxysms of convulsion are phenomena too different to have the same cause; the contractions are not owing, I submit, to cerebral discharges, but to suspension of cerebral influence on anterior horns for the hands and feet—the function of the cortical cells being, I mean in most cases of laryngismus stridulus, lost from supervenosity.

I have only spoken of respiratory fits in very young children. It is current doctrine that they are very prone to fits, and I have now to consider how it is that they are so, or rather to those I call lowest level fits. The breathing of the infant is diaphragmatic; the pyramidal tract is not fully developed in the infant; according to Soltmann inhibitory nervous arrangements are but little developed in very young animals and if so little in the human infant; it is well known that very young children tolerate large doses of belladonna (a paralyser of the endings of inhibitory vagus fibres in the heart). In the infant up to 1 year of age the respirations are 44; I suppose that this great rate is partly on account of little higher-level inhibition of the respiratory, medulla, centre; this inhibition gradually increases as the child grows older and then its breathing becomes less frequent. A healthy infant's breathing may be irregular with short pauses (Henoch), a slight resemblance to Cheyne-Stokes's respiration. Dr. Goodhart[8] remarking on Cheyne-Stokes's respiration, writes: "The respiratory centre goes back to its less educated form, and reproduces, in an exaggerated way, the rhythmical character of the respiration that is more or less natural in infancy." I suppose there is evidence here of less inhibition of the respiratory centre in infancy.

I submit then that we may conclude that, in comparison with the adult, the lowest level centres, especially the Superior Centres, are in infancy little governed (positive motor) and little controlled (negative motor) by the higher levels; that the lowest centres, and in particular the respiratory, medulla, centre, are in consequence naturally, healthily more excitable than in older people. Moreover the lowest level in the very young, the newborn infant, although the most advanced in development of all three levels of the cerebral sub-system, is incompletely developed.

I now consider in outline the Process of Evolution. Strictly we should begin with parts of the body; they make up the lowest level of evolution of the whole organism. I shall deal only with motor evolution, a very arbitrary proceeding since evolution is sensori-motor. I follow Herbert Spencer, using, however, terms more familiar to medical men than he uses; Spencer is not, of course, answerable for them, and I hope that any misinterpretations I may make of his doctrines, or misapplications of any of them, will not be put down to him.

There are four factors in evolution. In the evolutionary ascent there is (1) Increasing Differentiation (greater Complexity), (2) Increasing Specialisation (greater Definiteness), (3) Increasing Integration (greater Width of Representation), and (4) Increasing Co-operation (greater Association).[9]

(1) *Differentiation.*—There is increasing complexity; greater complexity the higher the level. The lowest motor centres represent all the muscles of the body in few different movements; the middle motor centres represent (re-represent) all the muscles in more numerous different movements; the highest motor centres represent (re-re-represent) all the muscles in most numerous different movements.

(2) *Specialisation.*—There is increasing definiteness of representation the higher the level. The movements represented by the lowest motor centres are for, comparatively, general ends, those represented by the middle motor centres are for more particular ends, and those represented by the highest motor centres are for most particular ends.

(3) *Integration.*—There is increasing width of representation by centres, the higher the level. Each of the lowest motor centres represents movements of muscles of some small region of the body (representation in detail). Each of the motor centres of the middle level represents movements of muscles of a wider region. Each of the (hypothetical) motor centres of the highest level represents movements of a widest region if not of the whole organism.

(4) *Co-operation.*—There is an increasing number of interconnections of centres, by fibres, the higher the level. The motor centres of the lowest level have few inter-connections; the motor centres of the middle level have numerous interconnections; the motor centres of the highest level have most numerous inter-connections.

I have in an earlier part of this lecture mentioned the Scale of Fits—Lowest, Middle, and Highest Level Fits. I now suggest a comparison and contrast between middle level and highest level fits as depending on discharges of levels of different evolutionary rank. The middle level fits I call epileptiform seizures; they are those described by Bravais in 1827. No one, nowadays, doubts that there is a discharge-lesion, or perhaps many would prefer to say "disease," of some part of the so-called motor region (Rolandic region) of the cortex cerebri of one-half of the brain in these cases. Highest level fits are those of epilepsy, the so-called idiopathic epilepsy, or, as I may roughly say, they are "ordinary epileptic fits"; I suppose that most of these seizures depend on a discharge-lesion of some part of the prefrontal lobe (motor province of the highest level) of one-half of the brain.

(1) (*a*) An epileptiform seizure begins very locally; (*b*) an epileptic seizure begins comparatively widely. (2) (*a*) in an epileptiform seizure the commencing spasm is particular, there is in the commonest variety a particular disposition or attitude of the thumb and index finger; (*b*) in an epileptic seizure there is not such a particularity of onset. (3) (*a*) In an epileptiform seizure the movements of *each region* are (comparatively) slowly developed; (*b*) in an epileptic seizure they are (comparatively) rapidly developed. (4) (*a*) In an epileptiform seizure the convulsion has a deliberate march, different regions of the body are involved comparatively distinctly, one after another; the convulsion becomes universal gradually; (*b*) in the epileptic seizure the convulsion has a rapid march, different regions of the body are involved nearly together; the convulsion is universal almost at once. In the following two statements it is not meant that what is given after a figure in one statement is the exact correspondent of what is given after the same figure in the other.

Do epileptiform and epileptic seizures, differing in (1) degree of localness of commencing spasms, (2) in degree of particularity of commencing spasm, (3) in degree of approach to simultaneousness of development of movements of *each* region, and (4) in degree of approach to contemporaneousness of development of movements of *several* regions, differ in these four ways because they depend on discharges beginning in (some part of) two levels which differ in that their centres or units represent (1) different numbers of different movements, (2) movements of different degrees of definiteness, (3) movements of regions of different extent, and (4) movements with different degrees of association with one another?

In accord with the hypothesis suggested is the fact that the difference between the two kinds of fits is not absolute; in the epileptic fit one side of the body is, at least often, affected a little before the other (turning of both eyes and of the head to one side is common) and a little more than the other. Indeed, I think, a very rapidly-developed epilepti-

form seizure approaches an epileptic fit in character; if so the hypothesis is further supported.

I suppose that in cases of epilepsy and of epileptiform seizures there is a very local discharge-lesion (physiological fulminate) in one half of the brain. I have thought that there are certain differences depending on different rates of liberations of energy by nerve cells (nervous discharges) in each kind of fit. With regard to liberations of energy by nervous elements, we have to consider two things or two aspects of one thing—quantity of energy liberated, and the rate of its liberation; the two varying factors both in normal and in the "excessive" nervous discharges of fits. With regard to the convulsion produced partly directly but mainly indirectly by a discharge-lesion, we have to consider the amount of convulsion, the range of convulsion, and the time in which that range is attained, and particularly whether the onset of the paroxysm is "deliberate" or "sudden." In two liberations of equal quantities of energy at different rates there is the same momentum or quantity of motion; but the *force* of the more rapid but shorter liberation of energy will be greater than that of the slower and longer liberation; using an old-fashioned term, the more rapid the discharge the more "intense" is the fit. The more rapid the liberation of energy by a discharge-lesion (primary discharge) the more numerous and greater the resistances which will be overcome, the more numerous, healthy, comparatively stable, elements will be compelled to discharge (secondary discharges); consequently the greater the amount of convulsion, and the wider its range.

I now make some general remarks on Dissolution. Dissolution from disease is rarely, if ever, the exact reverse of evolution. When we consider nervous maladies as Dissolutions we have to bear in mind not only the Dissolution, that which is effected by diseased, but the Evolution going on in the undamaged, healthy, remainder. There are some obvious exceptions to the implication that a range of evolution in cases of Dissolution remains; for example, in absolute dementia, if there be such a thing, there is no lower range of evolution remaining in the highest level, all "layers" of it being functionless. Taking the case of insanity for illustration, and ignoring that extreme degree of it which I have spoken of as absolute dementia, I submit that whilst the negative affection of consciousness in every insanity answers to the dissolution, loss of so much, the positive mental symptoms, illusions, delusions, etc., signify Evolution going on in the healthy remainder, going on in parts which disease has spared, going on in the lower, but now highest, range of Evolution of the highest level. He who is studying the physical process during positive mental symptoms, or to take a particular example, during an illusion, in any case of insanity, is as certainly dealing with evolution as he is who is studying the physical process during a perception in a sane person; indeed, the illusion is the insane man's perception.

Dissolution is from the least towards the most organised. It is necessary here to remark that such an expression as "high organisation" is not, when used with regard to the nervous system, synonymous with most complex, etc.; indeed, the most complex, etc., nervous arrangements, centres and levels, are the least organised; the most simple are the most organised. Thus the centres of the lowest level are much more strongly organised than those of the highest level are. It is very important to bear this in mind. A man deeply comatose from sucking raw spirits out of a cask, and whose highest level or, presumably, most of it, is rendered quite functionless by much alcohol rapidly taken, recovers because the "vital" centres of his lowest level are very strongly organised and go on working, although imperfectly, when the comparatively weakly organised centres of his highest level speedily "give out." If the "vital" centres of the lowest level were not strongly organised at birth life would not be possible; if the centres of the highest level ("mental centres") were not little organised and *therefore very modifiable*, we should make few new acquirements. The highest level is supposed to be less and less organised and therefore less and less automatic the higher the "layer"; the highest layers are the least organised, least automatic and are attended by most vivid consciousness; they are most easily rendered functionless by certain general injurious agencies, as when there is delirium in such non-nervous diseases as pneumonia, whilst the function of the lower (more organised) layers persists; the positive mental symptoms of the delirium occur during activity of, during evolution going on in, the functionable, lower, more organised "layers" of those centres.

There is another relation of the several levels to one another, the consideration of which is very important, from a medical point of view. Schroeder van der Kolk[10] has stated that the spinal cord of a sturgeon weighing 120 lbs. is about equal in thickness to that of a frog; he says "that the more complicated their [animals] movements, the more numerous will be the ganglionic cells with their several groups, and thicker will be the anterior horns and the masses of grey substance in the spinal cord." Herbert Spencer has written to the same effect, but more generally.[11] The principle involved is well illustrated by Horsley and Schäfer[12] when speaking of what they call the trunk area of the motor region of the cortex cerebri; they write: "It certainly is not a little remarkable that the numerous and powerful muscles of the spine should be governed from so small a portion of the cerebral cortex, but it is to be remembered that the movements of which the spine is capable are comparatively few and simple."

This seems to show that motor centres are voluminous—contain more cells and fibres—not in proportion to the size of the *muscles* they represent, but in proportion to the number of different *movements* of muscles which they represent; the higher the level the more numerous different movements does it represent, along, of course, with corresponding impressions (sensory element) which I am neglecting. It is clear that the cerebral hemispheres are much more voluminous than all the centres of the lowest level put together are; but it cannot be said that what I call the motor province of the highest level, the prefrontal lobe, is, or is much, more voluminous than the motor province of the middle level (Rolandic region); I speak on this matter later.

I think we may say that the higher the level, limiting consideration to the motor provinces of the levels, the more tolerable is destruction of a given number of cells (destruction-lesion) and the more intolerable is high instability, instability far above normal, of an equal number of cells (discharge-lesion). For the higher the level the greater the number of different movements it represents and the greater is the intricacy of the level. (See part of the lecture on the Process of Evolution for qualifications). To take the case of destruction-lesions first; suppose a destruction of so much (1) grey matter of motor centres of the lowest level as would paralyse one arm completely; I submit that a loss of (2) the same quantity of grey matter of the "arm centre," a motor centre, of the middle level, would produce only weakness of the limb, and that (3) a loss of the same quantity of the motor province of the highest level (of any part of it I may say) would produce very little, if any, obvious effect on the arm. If what was said on the evolutionary process be true, it follows that the higher the level the greater the Compensation for a destruction-lesion, or, as I just said, the more tolerable is that kind of lesion. It is quite otherwise in the case of discharge-lesions or, synonymously, physiological fulminates; indeed, there can be no compensation for a discharge-lesion. I will illustrate by the effects of discharge-lesions of the middle and highest levels, that is by epileptiform seizures (the epilepsy described by Bravais in 1827) and seizures of so-called idiopathic epilepsy. The highly unstable cells of a discharge-lesion (or physiologieal fulminate) remain connected with other (no doubt, in gradually increasing degrees of indirectness, with all other) normal, healthy, comparatively stable, cells of the level of which such a lesion is a small part; most of the fit is beyond question owing to secondary discharges (induced by the primary discharge, that of the fulminate) of these normal cells (there is next, of course, discharge of cells of a lower level or of lower levels). The higher the level the more numerous are the normal cells which, upon discharge of the local fulminate can be compelled to co-operate in its excess, since the higher the level the more "intricate" it is, the greater the number of inter-conneetions. (Co-operation in Excess is, so to say, Compensation inverted).

The motor province of the highest level is not, I have

acknowledged, more, or not much more, voluminous than is the motor province of the middle level. I now consider this matter. Evolution is not an "even process," not one to be properly symbolised by the raising of an expression to a higher power, called Involution in algebra. If I may put it so, increasing evolution in the nervous system may, at least in some cases, be likened to the raising of some parts of an expression to a higher power than other parts of that expression are raised to. From theoretical considerations I think that in man the motor province of the highest level (a division of the "mental centres") represents very many movements of parts of the body which have small muscles (properly small movements) and that it represents comparatively very few movements of the parts having large muscles; if so it especially represents most complex movements of the ocular muscles, of the muscles of the hands, and of those of the tongue, lips, and palate; these are movements represented (of course, with corresponding sensory elements) in the physical bases of visual and tactual ideas and of words in the highest level ("mental centres").

The main elements of that part of mind which is commonly distinguished as intellect from the other part called emotion or feeling, are Visual and Tactual ideas and Words. Much the greatest part of mentation, both in the sane and the insane, is carried on in visual ideas; if all visual ideas were cleared out of a man's mind he would became practically mindless; there will be a very great representation of ocular movements in the highest level. Further, much mentation is carried on in tactual ideas. Herbert Spencer[13] has pointed out that intelligence in animals is proportionate to the development of tactual organs; to use his words: "a highly-elaborated tactual apparatus comes to be the uniform accompaniment of superior intelligence"; there will be a great representation of movements of the hands in the highest level. I suppose no one denies that words serve in all higher thought, in what has been called conceptual thought. I think that the physical bases of the psychical things we call words are audito-articulatory nervous arrangements and suggest that highly complex and special movements of the tongue, lips, and palate are represented in the highest level.

It is interesting that, according to Weir Mitchell, after amputation of limbs the parts of the lost limbs which remain spectrally, or I might say mentally, present to the patients are the terminal parts, hand and foot; the sufferers are, in most cases, unconscious of the part between the phantom hand or foot and the stump, if I may be pardoned this expression; they are "conscious of the parts" having small muscles; here is some indirect evidence that those parts are much more represented in the highest level than the parts having large muscles.

In this connexion I draw attention to a very interesting paper by Mr. F. H. Bradley.[14] In introductory remarks Mr. Bradley asks: "Why, when we strive to move in dreams do we not always move?" Perhaps this accords with the hypothesis that large movements are but little represented in the highest level ("mental centres"). Mr. Bradley makes the interesting remark that dream movements are easier in some dreams; "thus, for example, it is common to move the lips and tongue and fingers" (parts having small muscles).

I think we may conclude, taking into account not only the physical bases of visual and tactual ideas and of words, but also the vast number of connecting fibres implied by the innumerable combinations into which these ideas and words enter, that the motor province of the highest level, if not more voluminous, is yet more intricate than the motor province of the middle level; and that destruction-lesions of the former are more tolerable than equal-sized destruction-lesions of the latter; the reverse for discharge-lesions.

NOTES AND REFERENCES.

1 *Med.-Chir. Trans.*, 1890. 2 *Brain*, vol. iv. 3 *Lancet*, December 22nd, 1894. 4 *Journal of Mental Science*, October, 1874, p. 401. 5 I do not say that all fits called epileptic (so-called idiopathic) are owing to discharge-lesions of parts of the highest level. There are seizures, called epileptic, depending on discharges beginning in parts of the temporo-sphenoidal lobe; convolutions of these lobes may not be parts of the highest level. 6 *Brain*, April, 1888. 7 For an able criticism of my opinions on this matter, see a paper by Dr. Gay; *Brain*, January, 1890. 8 *Clinical Journal*, March 1st, 1893. 9 The word "comparatively" is to be understood here and in many other places. 10 On the Spinal Cord and Medulla Oblongata and on Epilepsy, *New Syd. Soc. Trans.*, p. 64. 11 *Psychology*, vol. i, pp. 35 and 55. 12 *Phil. Trans.*, vol. cxxix, 1888, B. 13 *Principles of Psychology*, vol. i, pp. 356 *et seq.* 14 On the Failure of Movement in Dreams, *Mind*, July, 1894, p. 373.

NOTES ON AN EXPERIMENTAL INVESTIGATION INTO THE GROWTH OF BACILLUS TYPHOSUS IN SOIL.

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UNTRACED SOURCES OF INFECTION.

IN probably over 80 per cent. of the reported cases of typhoid fever the origin of the infection cannot be ascertained with any certainty. Usually some insanitary conditions in the surroundings of the patient are credited with giving rise to the disease. It is common experience that in a majority of cases when the sanitary condition are remedied, further cases of the disease are prevented. Again, it is also a common observation that so long as insanitary conditions exist cases of typhoid fever are apt to recur at longer or shorter intervals.

From observation and experience during a number of years it has become now, I think, generally accepted that the typhoid poison is generated outside the human body, and gains access by a great variety of ways.

The evidence, too, which has accumulated during the past few years must put it as almost beyond doubt that the bacillus typhosus of Eberth is the exciting cause of the disease we term typhoid fever. The theory, therefore, that the bacillus typhosus is fairly widely distributed in Nature, and that it is capable of living, and possibly of growing, for long periods outside the human body is one which, I think, is generally accepted, and is one which experience has shown to be of much value in the prevention of typhoid fever.

"TYPHOID AREAS."

It was my good fortune to have for several years exceptional opportunities of observing the special features of endemic typhoid fever in my capacity as Medical Officer of Health at St. Helens, one of the most typhoid-stricken towns in this country. Among the many interesting points in the natural history of the disease which one observed was that there were certain areas in which the disease showed a special tendency to recur at varied intervals.

One of the most marked examples of such an infected area occurred in a group of seven cottages in which 18 cases of typhoid fever were reported in eight years and a-half. Apart from the fact that these cottages had unpaved yards and privy middens, they were in a good sanitary condition. Perhaps 5 or 6 of the total number of cases were caused by direct infection, but the remaining cases occurred at intervals and under such conditions that one could arrive at no other conclusion but that there was some local source of infection which had existed in this locality during the whole of that period.

The above is an exaggerated example of what one observed in a great many other districts of the town.

EXAMINATION OF THE SOIL.

The question naturally arose as to where the actual propagation of the disease-producing organism took place. It appeared to be a matter of the first importance to determine this; because, having done so, one could the better formulate a scheme for the destruction of the infecting material.

With this object in view, I undertook a rather laborious research, during the first portion of which I was associated with Dr. Maitland Gibson, my assistant, to whose zeal, accuracy, and careful work I shall ever owe a debt of gratitude.

In the first instance, samples of soil—using the term "soil" in its widest sense—were collected from what I considered the most "probable" of the areas. These were examined by the methods which are detailed later with a view of finding the typhoid bacillus if it were present. Thirty such samples were collected and examined. In not one single instance was B. typhosus found. In many instances parallel control experiments were carried on with duplicate samples to which had been added small quantities of fresh culture of B. typhosus.