Remarks
ON
GUNSHOT WOUNDS OF THE HEAD.

MADE IN OPENING A DISCUSSION AT THE MEDICAL SOCIETY OF LONDON ON FEBRUARY 8TH, 1915.

[WITH SPECIAL PLATE.]

BY SIR VICTOR HORSLEY, F.R.C.S., F.R.S.,
CAPTAIN, R.A.M.C.(T.),
CONSULTING SURGEON, UNIVERSITY COLLEGE HOSPITAL; SURGEON, NATIONAL HOSPITAL FOR THE PARALYSED AND EPILEPTIC, QUEEN SQUARE.

THE subject of gunshot injuries of the head is, of course, an enormously wide one, and it includes not only the important question of how the actual injury to the brain is produced, but the subject can clinically also be profitably discussed from another point of view altogether, namely, causes of death and how to prevent them.

I shall to-night speak more in the former direction, and especially because I have not been permitted to see any cases in the present war, except a few exceptional instances which happened to be referred to me unofficially.

PHYSICAL EFFECTS PRODUCED BY HIGH VELOCITY BULLETS.

I made a large number of experiments[1] on this subject over twenty years ago when the .303 rifle was introduced into the services, and the results were fully confirmatory of those in part arrived at previously and independently on the Vetterli rifle by Professor Kocher, especially as to the so-called explosive effect of high velocity projectiles. It occurred to me then that what was required was a registration method. To this end I employed modelling clay, a substance which roughly resembles the tissues in that it contains a considerable percentage of water in its interstices, but differs with advantage in that, when disrupted, it remains exactly as the explosive force had deformed it, so that all that was necessary was to fill the cavities produced by the bullet with plaster-of-Paris and thereby obtain an absolutely accurate record of the whole effect of the shot. The method immediately showed several things: First, that the so-called explosive effect was directly proportional to (1) the sectional area of the bullet, (2) to its velocity, (3) to the amount of water present in the substance through which a bullet passes, and (4) that the forces of disruption were at an angle to the axis of the flight of the bullet, which I have never been able to completely determine. I have obtained by means of the clay-plaster method further points concerning the ballistics of the projectile which could not be reached in any other way. The most practically important for our present subject are: (1) Where in the course of the bullet is most mischief done? and (2) by what force?

(1) *Where Most Mischief is Done.*

The casts show that the maximal disturbance is produced, of course, as soon as the bullet at its highest velocity is surrounded by the largest mass of wet tissue.

In the animal the conditions are governed by other considerations, of which the most important is that the water-holding material is surrounded by an elastic skin, and that the so-called larger aperture of exit necessarily results from the driving out of the limb or trunk all the fragments of tissue, bone, and particles of fluid to which the velocity of the bullet has been communicated. The larger aperture of exit is a matter, therefore, of what happens to be struck in the interior of the skin envelope.

(2) *Forces Producing the Injury.*

These relate to the two movements of a bullet: First, its progression forward; secondly, its spin around a central axis given to it by the rifling.

It is ordinarily assumed that the progression forward movement is the more important, but in my opinion it is not so, although, of course, the amount of injury naturally depends on the length of traverse of the body by the bullet.

The most important movement from a pathological point of view, I suggest, is the rotary spin, and I came to this opinion by observing, to my surprise, that the rotation of the bullet was still visible on the plaster cast even up to the moment when the bullet ceased to penetrate any more.

It is quite clear that in these circumstances the disruption of the tissues must be attributed in the main to the rotating forces of a bullet, and the transverse section of a plaster cast of a bullet fired into wet clay, in which, therefore, there is a maximum disruption due to the water, shows that the particles of fluid are thrown off practically at right angles to the axis of flight.

It is interesting to notice also in some of the casts that these disruptive tears have very often a spiral direction antero-posteriorly, the turns of which are of the same length as the spirals of the grooves of the rifle.

Sometimes these have also shown an interesting degree of direction backwards, and then the tear is circumferential to the axis of flight, which reminds one very forcibly of the compression waves of air shown in Professor Boys's beautiful photographs of a .303 bullet during its flight. It is clear that if the density of the clay varied suddenly, as it does not infrequently, the results would be a fixation in the plaster of the disruption wave quite comparable to that of the more labile fluid air, as in Professor Boys's experiment.

Shape of the Bullet.

We must now consider the question how far the shape of a bullet affects the question of degree of destruction.

(a) *Sectional Area.*

The so-called explosive bullet, or dum-dum, is a soft-nosed lead bullet, which deforms very easily, and by its expansion greatly increases the sectional area.

Very considerable confusion seems to have arisen recently, because the modern jacketed rifle bullet having been made more and more pointed until there is a very great contrast between the long sharp nose and the flat base, it has actually been supposed that this bullet makes a much worse wound if it advances through the tissues base foremost instead of the apex, whereas, of course, the result being proportional to the sectional area, it makes no difference.

This brings me to the next point, of which a good deal has been made on purely hypothetical grounds—namely, the question of the modern pointed bullet turning over during its passage through the tissues. Undoubtedly turning over of an elongated projectile is a very common event. To find out whether it was more common now with the modern shaped bullet than with the old conical projectile, I asked Mr. Daw, of Messrs. Hollands and Hollands, to kindly make for me some .22 calibre cartridges with bullets of the same weight as the ordinary conical pattern, but pointed like the modern service projectile, and, of course, with the same load. This he very kindly did, and photographs are reproduced (Figs. 1, 2, and 3) of the records of experiments made by the clay method under as nearly as possible similar conditions, the first being an imitation service bullet, the second the old conical pattern (both these being .22 calibre), and the third the larger .310 soft lead bullet, to contrast with the service bullet, and to settle again the question of the deformity caused by the various projectiles. This point, I may mention, I had already dealt with in my first experiments twenty years ago, which, as I have already stated, went to show that the apex of a bullet had no bearing on the immediate question of amount of destruction. I have also dealt with it in a report furnished to Lord Kitchener and published by him.[2]

Turning over.

Some misconception as regards turning over has arisen, because it seems to be imagined that a very pointed bullet might turn over and over round a transverse axis through the middle of its length, progressing in fact like a wheel, but this is not the case; it only turns over once. Turning over is very common, but, as is shown when the bullet enters clay or soap, it does not happen until nearly half its course has been passed over, that is, when the progressive velocity is greatly reduced, and the advance of the bullet becomes more sensitive to obstructions which will first affect the light tip, the momentum of which is very different to that of the base. Further, in consequence, no doubt, of the greater obstruction and friction set up when the bullet travels at right angles to its long axis,

its traverse of the tissues is much reduced, but the spin due to the rifling continues to the end

As regards the disturbance of the tissues caused by turning over, the net result is conversion of a tubular wound (see esp. Fig. 1) into a cleft which is nearly triangular in cross-section, a narrow isosceles triangle, the base of which is caused by the base of the bullet, and the apex, of course, by the point. When turning over has reached its complete development, there is certainly rather more appearance of disruption, but on measuring the circumference of such a cast there is little difference between the "turned over" region with the immediately pre-cursory cylindrical part of the bullet's course. The practical conclusion which follows from these facts is, of course, that "turning over" is not to be credited, as it has been, with doing much harm, the real cause of great destruction of tissue, etc., being, of course, the high velocity and rapid spin.

Fragments of Bone.

The clay-plaster method showed me another fact that I had not considered fully. It is that the deep penetration of the brain by a fragment of bone is in the first place the simple consequence of the high velocity of the bullet being communicated to such bodies much lighter than itself, and therefore capable of proceeding as far and even farther than the shot.

In view of the fact that any such fragment may be infected, it follows that at the first operation every reasonable search must be made for fragments, as they certainly may later cause the death of the patient.

Dr. Bruce's beautiful radiogram reproduced in Fig. 4 is an interesting example, because the shrapnel bullet, partly caught by the edge of the hole, nevertheless has sent on five fragments, one streaked with lead, deeply into the brain. This was the case of an officer who came under my care some ten days after he was wounded at the end of August. There was a foul small round wound above the left frontal eminence which Dr. Spitta found was infected with *Staphylococcus aureus*, and it led into an abscess cavity about 2 in. deep. I removed the purulent débris, fragments, etc., cut away the original wound in skin and bone, and disinfected with sublimate lotion, hydrogen peroxide, and weak carbolic. Vaccination with autogenetic vaccines was carried out by Dr. Spitta for two months. The patient has made an excellent recovery; the cavity has, after three months, cicatrized and he has returned fit for light duty.

The distance of penetration of the bone fragments in this case is exaggerated, of course, by the retention of the shrapnel bullet on the inner edge of the hole.

CLINICAL FEATURES.

Perhaps the most important subdivision of clinical conditions which are special is that of causes of death.

1. *Concussion.*

Several cases have been reported of fatal concussion without penetration of the skull. These are, of course, perfectly possible because they fall into the same category as the deaths caused by the simple blow of a cricket ball. They are apparently due to direct paralysis of the respiratory and cardiac centres in the bulb. Mr. Walter Spencer and I showed many years ago that mere pressure on the unopen skull, if sufficiently severe on thin parts, could affect the intercranial tension so as to interfere with the functional activities of these centres.

2. *Rise of Intercranial Pressure.*

Duret showed many years ago that the most paralysing effects on the centres of organic life were produced most easily by force applied in what he called the fronto-bulbar axis, and he showed that the effect of shock applied to the frontal region was transmitted largely by the cerebro-spinal fluid to the interior of the ventricles and even to the fourth ventricle. This is undoubtedly the first effect of a gunshot wound to the head and evidenced by functional inhibition of the respiratory centre, as Kramer and myself showed first in 1897. Concurrently, one has, of course, immediate haemorrhage, and therefore an equal immediate rise of intercranial pressure. If this is not relieved, the embarrassed respiratory centre fails. At the same time the vagal centre is at first stimulated and causes very slow beats of heart, and, as the pressure rises, this gives place to paralysis of the vagal mechanism, and then begins the fatal and final stage. Probably a certain number of deaths in cases of this kind could be saved by immediate operation, and I have under my observation now an officer, whose radiogram is shown in Fig. 5, whose life was so preserved by Major Sherran, R.A.M.C., who, recognizing the urgency of this condition just described, operated at the field dressing station within a very few minutes of the infliction of the wound by trephining and washing out the extravasated blood, thus releasing the pressure and saving the patient's life. The patient is now gradually recovering. In many cases, if there is a good blood pressure, the intracranial tension often prevents a rapid haemorrhage.

3. *Sepsis.*

This is of course primarily and in the vast majority of cases due to incomplete disinfection of the original wound, but also to the fatal and detestable practice of "leaving head cases alone," which, being the outcome of ignorance, both of the functions of the brain and of the principles of antiseptic surgery, led many surgeons of the old school (some of whom apparently still survive) to leave a patient to steadily die rather than perform the duty of attempting to save him.

I believe this wicked tradition was also in part created by the fact that the leucocytic barrier, whether subdural or intracerebral, was occasionally quite equal to fighting off the infection; and because such a neglected patient got well, the non-comprehending surgeon said, "Let us leave head cases alone as a rule!" It is to the credit of the British Army Medical Service that they showed in their observations and work during the Boer war the falsity of this error. We may hope, therefore, that the example of the brilliant surgery of officers like Major Sherran will prevent cases arriving in England under conditions hopeless for restoration both of life and function.

One word on general septic infection. Suppose the subdural space is infected and cerebro-spinal meningitis results. Are these cases necessarily fatal? Evidently they are not, as, indeed, Mygind has always contended.

What is to be our routine? A case I saw with Dr. Fraser at Southampton, and which I hope he will publish, suggests that the course adopted in that instance might be generally tried—namely, free opening and disinfection by irrigation of the cranial subdural space at the seat of the injury, a liberal lumbar puncture (1½ to 2 oz.), repeated if improvement arrested, and autogenetic vaccine treatment.

I understand that at Cambridge repeated lumbar puncture has been most efficacious in the treatment of the parallel condition of epidemic cerebro-spinal meningitis.

4. *Hernia Cerebri.*

A great deal of unnecessary importance used to be given to the condition known as hernia cerebri, as its occurrence was proportionate to the septic decomposition which characterized the condition of most of the wounds. In consequence of this latter factor we must divide the subject under the two headings of aseptic and septic hernia.

Aseptic.—In consequence of the explosive effect of a bullet on the normal brain, if portions of the bones of a skull are carried away—as, for instance, in the formation of a gutter—then the rise of intracranial tension will cause a certain amount of extrusion of the brain substance. This is accompanied by extrusion of the lacerated brain against the edges* of the opening in the skull. Owing to haemorrhage in the brain substance produced by the explosive effect, such a hernia tends to remain only just so long as there is increased intracranial tension, as, for example, in the cases of removal of cerebral tumour, where aseptic herniae can be studied not infrequently.

Septic.—I come now to the more difficult question of septic herniae and their significance. An infection of the bruised brain may present simply a localized suppurating cavity, in which case there is no hernia. If, however, the leucocytic barrier of the cavity is imperfect and the hemisphere in consequence happens to become the seat of general cerebritis, then hernia of necessity follows, and if the mischief spreads the hernia increases because of the spreading infective

* Thus aiding in the formation of a subdural leucocytic barrier, as was first made clear by Schäfer.

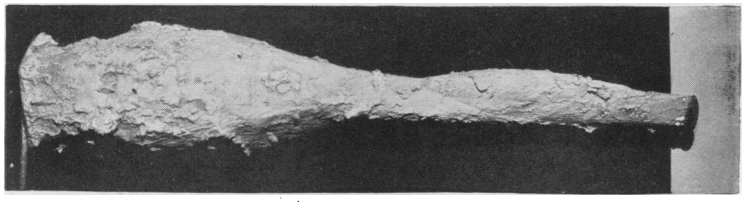

FIG. 1.—Pointed (Service) Bullet, .22 cal.; Cast of Effect in Clay. The tapering of the cast shows the gradual loss of velocity. The bullet is seen at the end of the cast, apex upwards. The narrow part of the cast is where the bullet began to turn over, and the track of destruction changed from cylinder to flat tear.

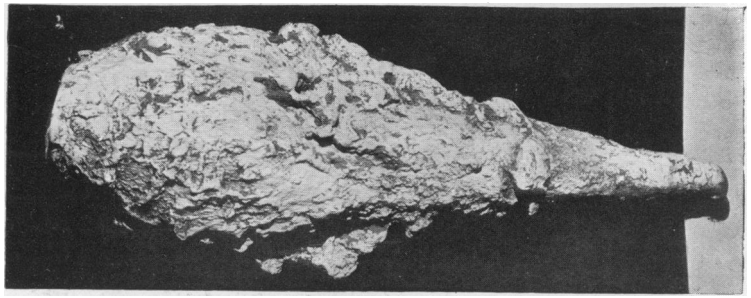

FIG. 3.—.310 Soft Lead Bullet; Cast of Effect. This cast shows the much greater destruction caused by a bullet of larger sectional area, and one which, being soft, deformed easily. Its penetration is proportionately lessened.

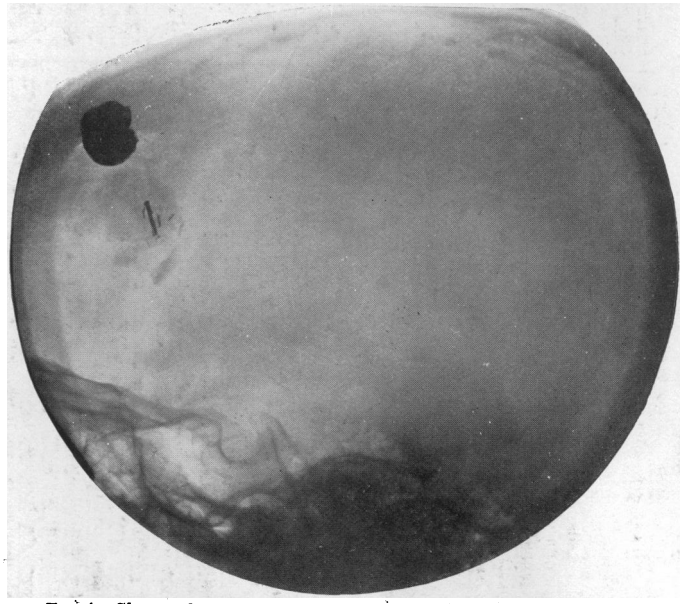

FIG. 4.—Shrapnel Bullet, showing Fragments of Bone Penetrating Brain deeply. The bullet is seen caught on inner edge of hole in skull. In front of it five fragments of bone, some streaked with lead, have passed into the frontal lobe. Around these was a 2-in. deep and wide abscess cavity, partly indicated in the radiogram taken by Dr. Bruce.

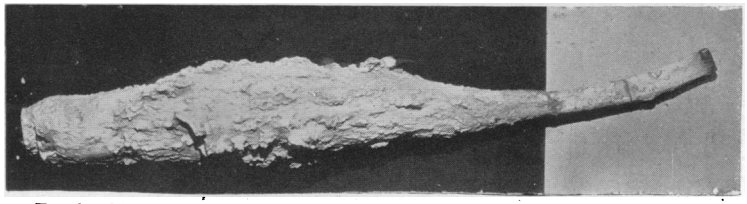

FIG. 2.—Old Conical Bullet; Cast of Effect. Similar cast of the effect of the old pattern bullet, which also turned over, so that the end of its course is a flattened cleft. The net amount of destruction is the same as in Fig. 1.

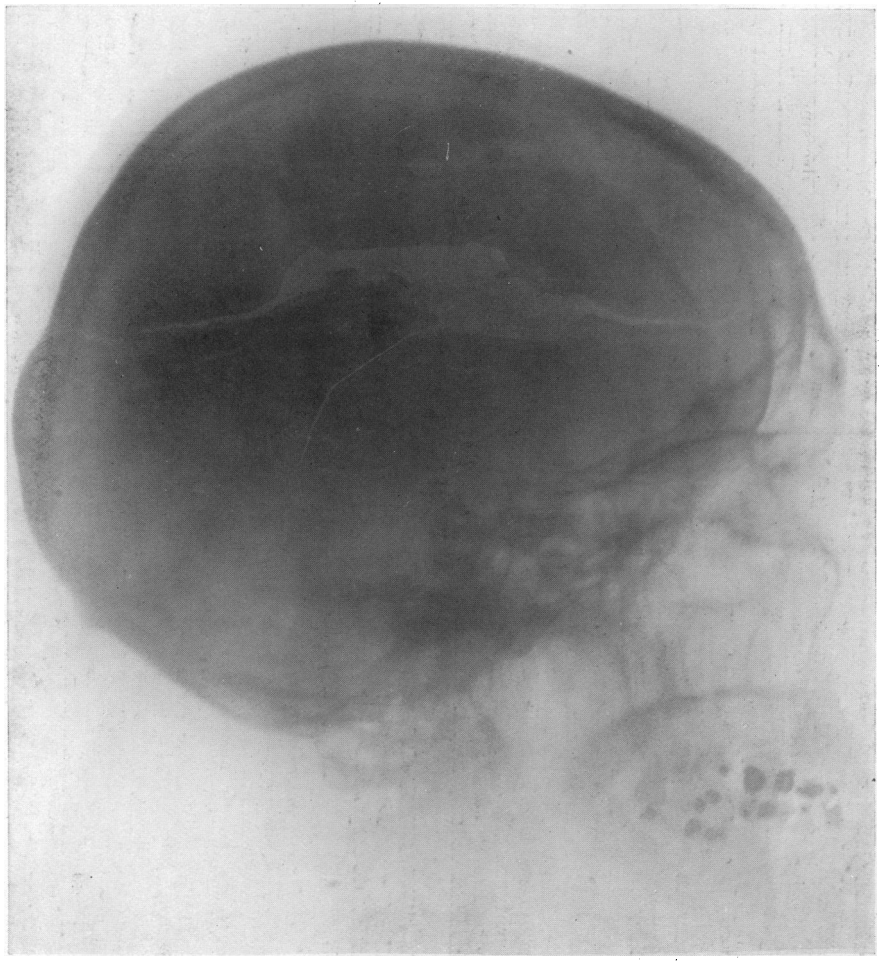

FIG. 5.—Fissuring Destruction of Skull and Subjacent Brain. In this case some of the bone was removed by Major Sherran's operation fifteen minutes after the wound to arrest the haemorrhage from the lacerated brain. The radiogram by Dr Bruce shows well the fissuring of the skull produced by the high velocity of the bullet.

oedema of the brain. The subdural leucocytic barrier may be quite effective in some cases, and yet the hernia increases. This was what one finds referred to very largely in the writings of the old surgeons, and in this case undoubtedly after some time some of the increase is due to the development of granulation tissue in the brain that projects. Such herniae, if the subdural barrier is good, yield completely to treatment with absolute alcohol and cutting away as the surface rapidly necroses. Various substances have been used for this purpose—for example, formalin—but for many years I have never found anything better than absolute alcohol.

Functional Disturbance of the Brain.

The first and most important practical question is how far compensation for loss of functions due to loss of cerebral substance occurs; possibly this is a question which, though attacked by neurologists for fifty years, must remain essentially indeterminate until the function of every part of the brain is accurately ascertained. It will be simplest, perhaps, to consider the matter by two examples — first, a sensory region of the cortex, and secondly, the kinaesthetic.

I desire to premise my examples by suggesting that in the human adult there is no evidence of compensation by education or substitution of function in other parts of the brain for function lost by reason of permanent destruction of given areas. Recovery due to absorption of haemorrhage and re-establishment of partly blocked circulation, however, may be expected to go on for several years if not interrupted by epilepsy and secondary mental change.

(*a*) *Sensory Cortex.*

The most specialized centre, and most clearly arranged topographically, is the visual area. I will therefore confine my remarks to that sensory function, and a case that I saw in October last with Dr. Simpson illustrates very well the problem. The patient, an officer in an infantry regiment, was hit by what was apparently a Mauser bullet on the right side of the head just below the parietal eminence. The bullet passed through the occipito-temporal region, making a deep gutter through the brain and under the skull, emerged through the middle of the right half of the occipital bone, and buried itself in the muscles at the back, where it was extracted by an incision on the field. The patient, who was totally blind, reached London (namely, the 3rd London Base Hospital) on about the fourth day after receiving the wound. Nothing was done to the wound on the head, so far as can be ascertained. When I saw him in a nursing home on the seventh day both wounds were inexpressibly foul; the posterior two-thirds of the head was oedematous, the patient, who, as before stated, was completely blind, could with difficulty be roused to an order, and his temperature was 101°. Under an anaesthetic the apertures in the scalp were explored by a large flap incision, and it was then found that in addition to the comminution of the skull at the apertures of entry and exit, there was also a line of fracture and comminution about 4½ in. long connecting the holes. Further, the whole lambdoid suture was started so that the occipital bone was loose—that is, both halves. On clearing away the fracture, blood and pus came from underneath the bone, but I considered that the subdural leucocytic barrier had already sealed off much of the subdural space. The wound was very thoroughly disinfected, irrigated with hydrogen peroxide, and sublimate lotion. As the flap incision was a very free one, no further incisions were made in the oedematous skin on the left side of the head. All lacerated portions of brain tissue were removed. Besides pus, there were several sloughy and dark pieces of tissue obviously necrosed. The bacteriological inspection of the head wound gave (by Major Embleton) an almost perfectly pure culture of the bacilli of malignant oedema. The patient has made a good recovery so far, after frequent dressings with hydrogen peroxide and weak carbolic lotion.

The immediate question in this case, however, is the recovery of sight. This began to return in the top right-hand corner of both fields, and has now spread until the patient can see probably over most of the upper right quadrant, but he is not a good witness. The first recovery of the upper part of the field in this central case interests me because I have shown that in peripheral lesions—that is, optic neuritis—the pressure is most severe on the upper half of the nerve and disc, and therefore preservation of sight is chiefly in the upper quadrants. (This patient had a remarkable congestion of his discs, but no true swelling.)

My immediate point is that no recovery has taken place in the gravely injured lobe, neither, I fear, can any be expected.

As regards the representation of the upper and lower halves of the visual field in the lower and upper parts of the calcarine cortex and the bearing of this further consideration on the present case, nothing can justly be said, seeing that the whole occipital suture being started there must have been bruising of some degree, even if slight, affecting the left calcarine region. Mr. Cruise, who has had charge of the case ophthalmologically throughout, will very kindly report on the case.

(*b*) *Kinaesthetic Cortex.*

The consideration of the loss of function of the Rolandic region is much more difficult, since paralysis of movement is no simple question of the destruction of a so-called motor centre, but also that of a number of sensation conditions and memories.

1. *Loss of Movement.*

So far as the loss of motor function alone may be discussed, I desire to suggest from the experience of cases who were wounded in the Boer war that the chief movements of the hand are not restored if the whole arm area of the anterior gyrus has been destroyed.

2. *Loss of Kinaesthetic Memories.*

The retention of power to move a segment of a limb at all is one thing, but the ability to effect that movement without clumsiness is quite another.

This depends on the conservation of what I term the topognostic sense, namely, the relation of a spot touched on the body, to our knowledge and conception of our position in space, and that chiefly in the relation of the spot touched to (*a*) the distance from the body—that is, "proximality"—and (*b*) the distance to the mid-line of the body, or "axiality."

The loss of the sense of appreciation of these relations and distances is what we call, in popular language, clumsiness, and I have shown that this topognostic sense is represented in both central Rolandic gyri. Further, I believe it is permanently lost if the arm area of both gyri is permanently destroyed. Thus far, therefore, there is no compensation possible by substitution activity of the lower centres.

Coarser co-ordinated movements of shoulder, elbow, wrist, and even of the hand, however, can be furnished by such lower activities.

References.

[1] *Proceedings of the Royal Institution of Great Britain*, vol. xiv, p. 228, 1895. [2] British Medical Journal, November 21st, 1914, p. 896.

Dr. Alfred C. Henderson, of New York, has published four cases of diabetes mellitus treated with fluid cultures of the lactic acid bacillus (*Journ. Amer. Med. Assoc.*, February 6th, 1915). Great care was taken about previous dieting; in three the diet enforced was equal to a carbohydrate intake of 15 grams. The conclusion Dr. Henderson draws from these four closely observed cases of diabetes is that no improvement was effected either as to the glycosuria or the acidosis.

At the annual meeting of the Federation of American Societies for Experimental Biology held in St. Louis on December 28th a resolution was adopted in which the Federation, after setting out that various European nations with which many members of the Federation were related by birth, descent, or intellectual friendship were now at war, extended to the scientific men within these nations the hope of an early and enduring peace which would leave "no permanent cause of rancour towards each other, and would ensure to each the glories of scientific and humanitarian achievement in accordance with its own conception of those ideals." The resolution may be taken as an indication of the desire of our American brethren to preserve strict scientific neutrality, and to hope for the best. The resolution is signed by the presidents of the Physiological Society and of the societies of Biological Chemists, for Pharmacology and Experimental Therapeutics, and for Experimental Pathology.