INVESTIGATION OF THE HISTOLOGY OF THE TISSUES, IMMEDIATE AND REMOTE FROM THE POINT OF INJURY, IN GUNSHOT WOUNDS OF THE LIVER, SPLEEN, KIDNEY, INTESTINES, BLOOD-VESSELS, SUBCUTANEOUS TISSUE AND APONEUROSIS, AND MUSCLES.

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It appears that the time has come when some generalizations on the special characteristics of gunshot wounds should be reconsidered in the light of the more extensive experience now available. For this purpose, wounds complicated by the super-addition of infective processes must be discarded, but exact knowledge of the extent and nature of the injuries produced by the passage of the missiles is an essential preliminary to the investigation of bacterial invasion.

As injuries sufficiently recent and in other ways suitable for some of the objects in view rarely reach the base, the assistance of Lieut.-Col. Kelly and Lieut.-Col. Ormsby was sought, and being willingly given, led to a number of the most useful specimens being obtained from casualty clearing stations.

It may be remarked that some of the examples dealt with below are wounds produced by shell fragments, and that in three instances three missile was retained, in others, the tissues were traversed by bullets the velocity of passage of which was not ascertained. It still remains to be proved, however, how far the actual velocity with which the bullet traverses the body affects the tissues beyond the actual area of the wound track; and clinical observation does not support the view that extensive injury, of the explosive-exit form, occurs independently of the bullet meeting with such resistance as is offered by bone—when the separated fragments, themselves endowed with motion, are responsible for the extensive laceration—or of an irregular impact of the bullet with the surface, and consequent rotation. In support of this view, evidence may be adduced from the large cavities produced in the interior of the limbs by fragments of shells which, in traversing the limb. have made but small apertures of entry and exit, or may even have been retained. Here a mechanism comparable to the spin of a cricket or golf ball explains the extent of the tissue damage more readily than any theory of expansion in the limb of air compressed by the passage of the missile.

That delicate structures may be so altered by concussion as to suffer either temporary or permanent abolition of function, is a familiar experience in injuries to the brain and spinal cord; but these organs, being enclosed in a firm bony capsule, scarcely offer a fair basis of comparison with the other organs of the body, even putting aside the special delicacy of their structure, and the high grade of the functions they preside over. In other organs and tissues of the body, concussion effects are but temporary in duration, and probably in

part due to the impression made upon the nerve-supply. At any rate, after two years of war, no evidence has yet been produced to show that permanent alterations in function of the solid viscera of the abdomen, such as might be expected from wholesale destruction of their secreting tissue, actually take place.

On the other hand, the production of limited areas of degeneration, as a result of interference with the arterial supply, is a familiar phenomenon; and the deductions to be drawn from the following observations would seem in favour of explaining the remote structural changes met with in the region of gunshot wounds as being due rather to vascular injury than to the effect of vibratory concussion or divulsive and expanding forces.

For the purpose of the present investigation, tissues have been examined as soon as possible after injury, and also after the lapse of sufficient time to permit of the observation of degenerative and regenerative processes, revealing injuries which might have escaped notice on earlier inspection.

LIVER.

Owing to the nature of the wounds, the majority of instances of injury to the liver which have come to my own notice at the base were of considerable standing, and being heavily infected, could not be utilized except with many reservations. Two were found which, while agreeing with Capt. Henry's description of two cases in which the liver was penetrated by fragments of shell or shrapnel case,[1] permit of an important addition. These specimens were both obtained from patients dying at a later date than that described by Capt. McNee and Capt. Stokes,[2] and at an earlier date than those prepared by Capt. Henry. They were selected for this reason, and also because one showed evidence of lateral pressure, and the other of the existence of well-defined patches of infarction at some distance from a tunnel-like track. The first was only twenty hours old, and the second six days.

The history of the first specimen is as follows: Among the multiple wounds produced by a bombing accident, there was one in the left axillary line, at the lower edge of the thorax. The missile had passed through the edge of the liver about three inches from the margin. The track made an angle of 135° at a depth of about an inch and a half, and came out with its centre about an inch and a half from the margin. The wound of entrance was stellate, with six limbs (*Fig.* 233, A). About three centimetres from the visible fissures there was a round pale-pink area, or rather a bleb, of the size of a split pea. Sectioning showed that a fissure ran up from the depth of the organ to the capsule, but without rupturing it. The wound of exit occupied about the same area as the entrance wound, but had only three limbs, and the appearance showed that there had been absolutely no loss of tissue. Pieces of cloth were embedded in the omentum, the splenic vein and the lower pole of the spleen were injured, and the missile was found just below the peritoneum.

The portions of tissue submitted to microscopical examination are shown in *Figs.* 233, A and B. That in A was cut into sections in a plane parallel to the surface of the liver, so as to include the tissue nearest to the track of the missile as well as the furthest extensions of the crack and tissue injured indirectly by the missile, together with some surrounding liver substance.

The tissue in B is a section into the depth of the organ, made so as to

pursue the course of the crack which is cut across in A. It will be observed in B that the fissuring evident on the peritoneal surface is reproduced in the depths of the organ by subsidiary fissures. There was no bile-staining anywhere. The microscope showed that both on the surface and in the depths the fissures followed for the most part the subdivisions of Glisson's capsule, and that where actual fissuring was not present, either a narrow track of hæmorrhage passed between the portal tracks and the cells of the lobules, or there was hæmorrhage into the connective tissue of the portal tracks themselves, resulting from injury to the branches of the hepatic artery. The bile-ducts were not observed to be disturbed except at the wider portions of the fissures, where they suffered in the disorganization affecting all the structures of the portal track.

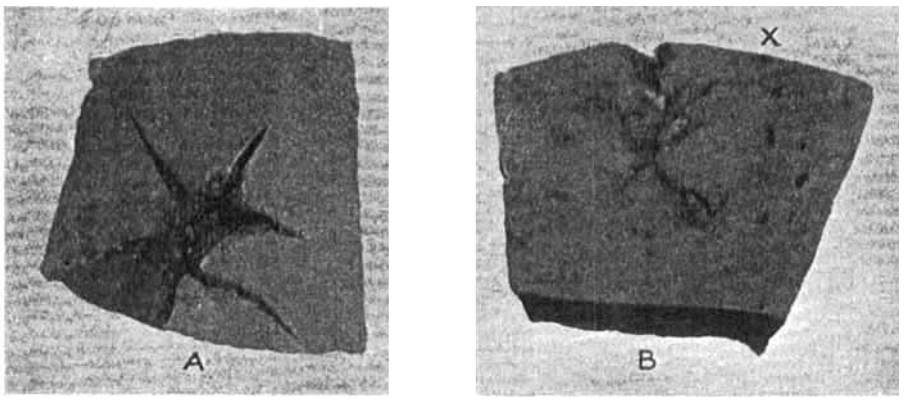

FIG. 233.—Liver. A. Entrance wound of bomb fragment, showing fissures of the capsule of Glisson. A slice has been cut off to show the extension of one of the fissures into the depths of the organ.

B. Deep extension of the fissure of the capsule. To the right, under the capsule of Glisson, a small bleb is seen at X which has resulted from the direct extension of a subsidiary fissure upwards. The finer fissures pass along the portal tracks for the most part. The surrounding liver tissue is normal.

The liver cells bordering on the exposed surfaces showed surprisingly little change. The ragged tissue lining the actual track was clothed by a thin layer of blood intermixed with cell débris. Beneath this there was an irregular but narrow margin of cells with altered, darkly-staining nuclei, or irregularly staining protoplasm, and the liver columns were in places widely separated, so that the intralobular bile-ducts could be distinctly recognized. There was also hæmorrhage between the cells of the lobules from the central veins in the immediate zone of injury.

It can be inferred that the subsequent course of the wound, had the patient lived, would have shown a tunnel track with a diameter corresponding to the extent of the fissures, and hæmorrhages, close to which a zone of fibrous tissue, as described by Capt. Henry, would have formed, to separate the track from normal liver. No remote disturbance could be found, but the interval of twenty hours may not have sufficed for the demarcation of any areas of infarction. It is obvious that the injuries offered ideal conditions for the spread of infection into the organ.

The localization of the greatest extension of the injury to neighbouring portal tracks suggests that, as the result of sudden pressure followed by immediate relaxation, the capillaries of the portal vein were torn across as they entered the lobule, in keeping with what one would expect from a missile entering a solid organ subdivided by ramifications of connective tissue. In the area of injury the liver cells themselves appeared to be little altered, but in some lobules they appeared swollen and widely separated, in others more tightly packed together than normal.

In the second case, a missile (nature not now ascertainable) entered the back at the angle of the left scapula, and passed down through the diaphragm and into the liver. The naked-eye appearances were very similar to *Fig.* 244 in Sir George Makins' paper,[3] and they correspond with Capt. Henry's description of a track "filled with bright chrome-coloured septic material, the margins consisting of very ragged, necrosed, bright-yellow, liver tissue. Outside this is a dense, well-defined zone of fibrous tissue which separates the septic track from normal liver. Patches of infarcted liver which have not undergone necrosis, and are recovering, are visible on either side of the localized track." To this description it is necessary to add that, in our specimen, there were in addition outside the fibrous tissue small areas of old hæmorrhage surrounding or contiguous to portal tracks, and that around these areas the liver cells were flattened and arranged in parallel rounded lines. In other lobules quite close to the injury there had been hæmorrhage around the central vein, from which the liver cells had been pushed aside; elsewhere there were isolated capillary hæmorrhages as if from blocking of the portal vein.

The description of the occurrence of regeneration in the liver tissue surrounding the infarcted areas may also be amplified, by stating that the histological appearances were those of 'new-duct' formation, described by Robert Muir in rupture of the liver, and by Milne after the experimental removal of portions of liver. They exhibited neither anything new nor anything about the actual occurrence of which there is any doubt, although there has been much controversy as to how the facts of the liver regeneration ought to be interpreted. It seems probable that a series of wounds of the liver of known age would greatly assist in clearing up knotty questions about regeneration in that organ.

Both specimens illustrate anew the fact that the injury to the liver is localized to the immediate neighbourhood of the wound, and so far as it extends it is continuous, neither of them can be adduced as supporting the theory of a vibration causing widespread and remote destruction of cells. The circumscribed area of degeneration found by Stokes and McNee, almost three inches from the line of a laceration extending only one and a half inches into the liver substance, also appears difficult to explain on the theory of remote vibrations. Were the liver not divided up by connective tissue, any waves set up would pass to Glisson's capsule as the ripples on a pool pass to the shore when a stone is thrown into the water. The portal tracks in the liver may interfere with the uniform propagation of the increase of pressure set up by a missile—and they probably do so, as the hæmorrhages in their neighbourhood go to show—but the facts indicate that the maximum of injury is present in the wall of the track and not at a distance.

Stokes and McNee do not describe the injury surrounding the track of their specimen. They mention bile-staining of the area, to which they attach importance. This would indicate that the bile-staining already existed before the wound was made—i.e., that the diseased area was antecedent to a wound which was only six hours old—as would also the fact of the young connective tissue containing a capillary and proliferating bile-duct, as well as the advanced necrosis of the liver cells shown in the figure accompanying their description. The absence of an extended zone of necrosis at the immediate site of injury is really one of the most striking features of gunshot wounds of the liver; and if it is absent here, why should it occur at a distance. These points will be illustrated in detail with reference to the kidney (see *Figs.* 236, to 245).

The liver, owing to its large size, is frequently the site of gunshot wounds, many of which are known not to have been fatal; nevertheless, after two years of war, clinical evidence of the late effects of injuries has not been placed on record. Equally significant is the pathological fact that when examining numerous slides, especially those of the second specimen above described, no evidence was obtained that the liver cells had anywhere (outside of the actual zone of injury) entered on a marked proliferation, such as is very prone to occur in the liver with slight provocation.

SPLEEN.

Valuable examples of injuries to the spleen were obtained from Capt. Charles and Capt. Mumford. *Fig.* 234 shows an extensive injury to the spleen

FIG. 234.—Spleen. (Capt. Charles's case.) The passage of the small piece of shrapnel shown was responsible for the extensive injury, the upper fragment in the figure having been entirely severed. There were no remote histological changes. Specimen obtained at operation a few hours after injury.

FIG. 235.—Spleen. (Capt. Mumford's case.) The missile grazed the surface of the spleen, and pierced the upper pole of the kidney. Extensive hæmorrhage around injury, but no remote changes. Specimen obtained eight days after injury.

produced by a small fragment of shrapnel case, one pole of the organ having been completely severed. The spleen was removed by operation, and microscopical examination failed to show any histological disturbance other than that due to hæmorrhage around the track of the missile and beneath the fissures of the capsule, possibly the extensive rupturing had liberated any internal pressure at the moment of its production, and thus obviated the subcapsular hæmorrhages which were sought for.

In the second case, the capsule of the spleen and subjacent tissues showed a stellate wound (*Fig.* 235), also due to shrapnel case. In this instance, too, no remote histological disturbances, or secondary effects due to anæmic infarction, were detected after death, which took place eight days later.

The spleen is, however, not very suitable for bringing out striking histological pictures such as those obtained with other organs.

KIDNEY.

Two valuable examples were again obtained from Capt. Charles and Capt. Mumford. In one, a bullet had entered near the upper pole, where it

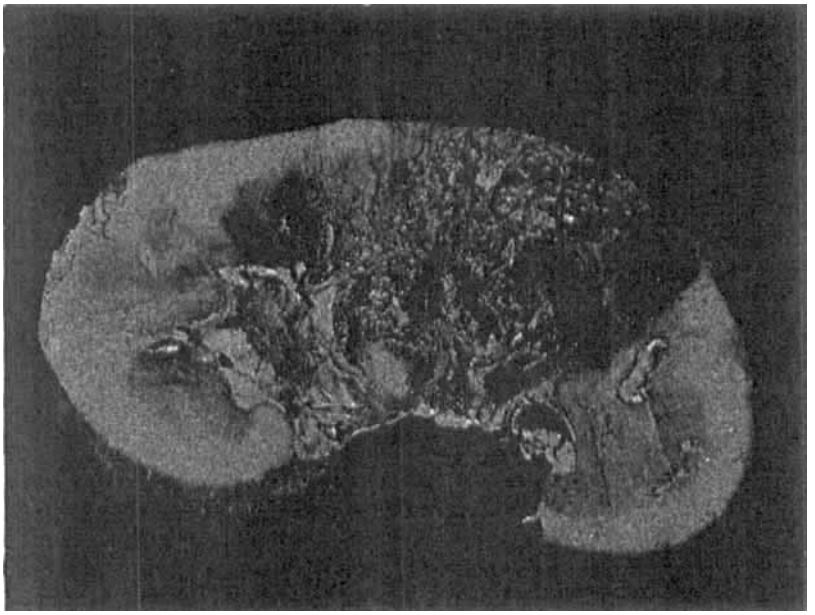

FIG. 236.—Kidney. (Capt. Charles's case.) The missile passed from one pole obliquely towards the other pole, where there was extensive loss of tissue. The other half of the kidney was cut in sections and examined microscopically (see *Figs.* 237, 238, 239, 240, 241). Specimen obtained at operation four hours after wounding.

made a three-limbed stellate wound, whose limbs measured 2 cm., 1½ cm., and 1 cm. respectively, exactly similar to those shown for the spleen in *Figs.* 234, 235. Passing obliquely through a long diameter of the kidney,

the bullet made a large pyramidal exit wound, with much loss of tissue near the lower pole. The organ was laid open in halves. The portion containing the wound of entrance was sliced in several directions, to permit of complete examination of the parenchyma. At a depth of a centimetre the wound was concavo-convex, ¼ cm. by 1·2 cm., filled with blood, and surrounded by a narrow blood-stained area. It almost immediately became a slit, the narrow surrounding zone of hæmorrhage being never more than ½ cm. to 1 cm. across. till it ended in the hole of exit. The larger vessels had been torn across in

FIG. 237.

FIG. 238.

FIG. 237.—Kidney. Track of missile near wound of entrance. Hæmorrhage filling track and running down towards pelvis. Retention of the normal anatomical relations of glomeruli and tubules. Compare *Fig.* 240, showing microscopical appearance above extreme right of track.

FIG. 238.—Portion of kidney bordering on missile track near wound of exit. Extensive hæmorrhage, with retention of anatomical arrangement of tubules and glomeruli. Hæmorrhage around the ureter, and beneath the epithelium of the calix. Inflammatory dilatation of the capillaries of the fat of the pelvis.

places. It will be seen from *Figs.* 236, 237, 238, 239, how little disturbance there was of the cortical, boundary, and papillary zones of the organ, or of the calices and their intervening fat, how little also of the vessels and the ureter. In the immediate zone of the injury, the epithelium of the tubules was found on microscopical section to be *in situ* in some tubules and desquamated in others. The perfect structure was retained in places in which the tubules were not only embedded in hæmorrhage, but also full of blood. This applies equally to the convoluted tubules, the descending and ascending loops,

and to the collecting tubules of Bellini. Towards the apices of the pyramids many otherwise healthy-looking tubules contained cells which had been desquamated higher up (*Fig.* 240). The finer details of cell structure were not revealed by the methods of fixing and staining employed, to which there was no alternative. The cells of the epithelium of some tubules near the injury appear swollen, and their nuclei shrunken. Apart from the hæmorrhage of the actual wound, there were scattered hæmorrhages in its vicinity, and, at a

FIG. 239.

FIG. 240.

FIG. 239.—Transverse section of the kidney from margin of track (exit wound) to inner surface. Hæmorrhage around exit wound, but no other visible disturbance. The microscopical appearances at the spot marked X on the figure are shown in *Fig.* 241.

FIG. 240.—Kidney. Microscopical appearance of tubules bordering on missile track (*Fig.* 237, left side of figure). The epithelium is swollen and its nuclei shrunken, although it has not lost its proper relations in some tubules, in others the cells are desquamated and have a different staining reaction, in yet others the lumen is filled with desquamated cells. Hæmorrhage in upper portion of figure. The absence of epithelial cells in some of the spaces surrounding the hæmorrhage is due to faulty fixation (see text).

distance, subcapsular hæmorrhages from the stellate veins, often of a minute size (*Fig.* 241). In the immediate vicinity of the wound the glomerular capsules were full of blood; but at a distance they showed, at most, a structureless content intervening between the glomerular capillaries and the capsule, or they appeared quite normal. The glomerular capillaries showed no visible changes. The epithelium of the pelvis and of the ureter showed no departure from normal, although the latter was embedded in hæmorrhage (*Figs.* 236, 237, 238, 239). There were small hæmorrhages in the fat between the calices,

and the adjacent capillaries in the fat were greatly dilated, as in commencing inflammation. They had therefore not lost their power of reaction. It will be remembered that the organ was removed only four hours after receipt of the injury, by which it had been almost entirely disintegrated; nevertheless, abundant islands of healthy kidney tissue could be found, many of the main branches of the renal artery or vein having been spared. The distribution of the injuries revealed by the microscope corresponded closely with those seen by the unaided eye, except that some of the more minute subcapsular hæmorrhages were only evident under the microscope.

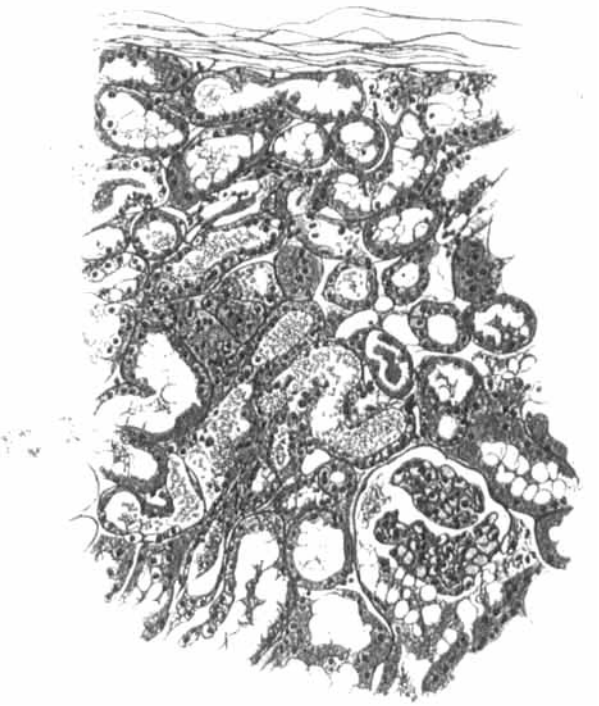

FIG. 241.—Kidney. Subcapsular hæmorrhage remote from wound. Some tubules with swollen epithelium, some apparently normal. Hæmorrhage or exudate into a Bowman's capsule (see *Fig.* 239 at X).

The second case of injury to the kidney forms a useful sequel to that just described, since the patient died eight days after it was received, and the extent of the injury is defined by the resulting degenerative and regenerative changes. Capt. Mumford supplied the following details: On June 2 a piece of shrapnel case entered the left side of the chest, and was thought to have entered the abdomen. The abdomen was opened on June 3 in search of a possible bleeding point, but none was found; for this purpose the spleen was specially examined, with negative results. On June 8 the patient had a raised temperature for the first time, and he died on June 10. An early autopsy showed an injury to the spleen (see *Fig.* 235), and a wound perforating

the upper pole of the left kidney. The perinephritic fat was loaded with hæmorrhage, and being adherent to the organ, it was removed with it. An orderly, who was instructed to place the specimen in 10 per cent formalin, inadvertently used 2 oz. of a 10 per cent solution in 1½ quarts of water. This solution dissolved out the blood pigment from the hæmorrhage; but happily the tissues were sufficiently well preserved to reveal the following later conse-

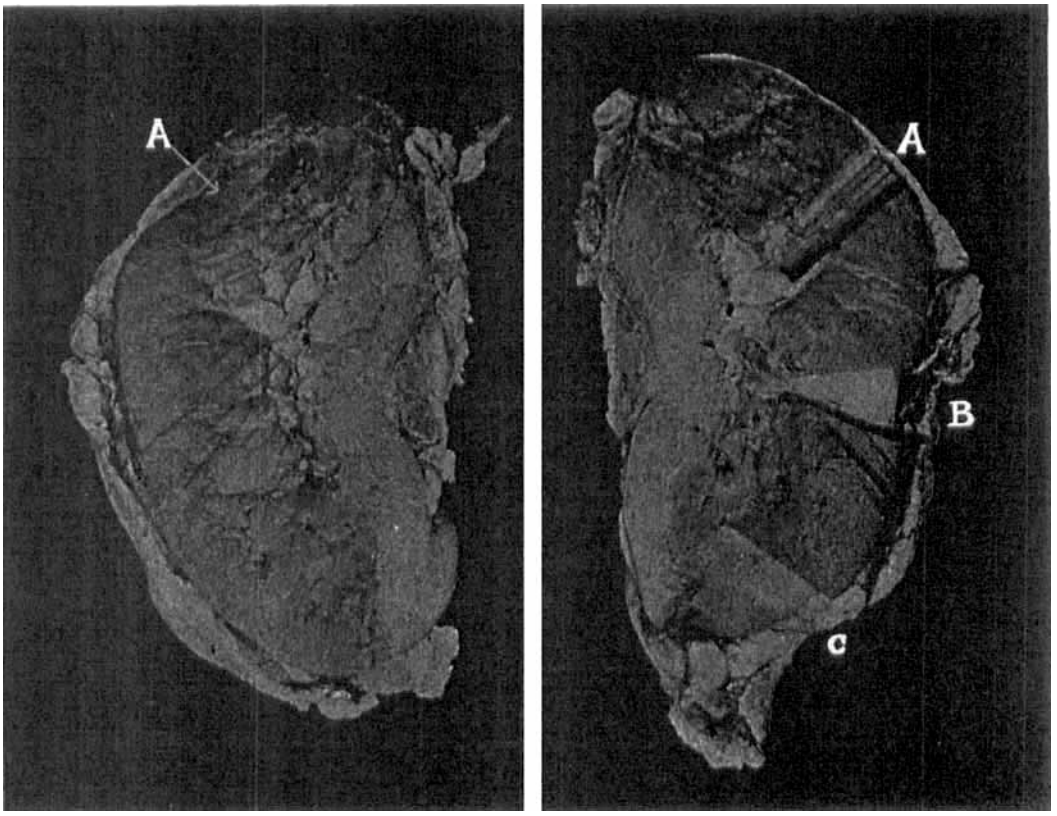

FIG. 242.—Kidney. Perforating wound of upper pole. Extensive hæmorrhage into perinephritic fat. Track surrounded by clot, which in its turn is bounded by a pale area into which blood pigment has diffused owing to the manner of fixation (see text). Hæmorrhage around track, but no other naked-eye changes. Portions were removed for microscopical examination from the half of the kidney shown on the right side of the figure. Of these, that nearest the injury (A) alone showed marked pathological appearances (*Figs.* 243, 244, 245). Specimen obtained at post-mortem eight days after wounding.

quences of the injury. Allowing for the manner of fixation, the cut surface presented unusual appearances only at the lower pole and surrounding the circular bullet track. There the tissues (*Fig.* 242) showed considerable laceration and hæmorrhage (and also blood-staining diffused by the imperfect method of fixation), extending from the margin of the upper pole in the cortex immediately under the capsule, past the wound for about one inch. This area

narrowed to less than half an inch in the boundary zone, and expanded again in the papillary zone. At its greatest extension it showed distinctly pale in colour in contrast to the adjoining dark kidney substance, and probably its true colour was obscured by the diffusion of blood pigment due to the faulty fixation. The pyramids in the area showed in places an exaggeration of the normal streaking. The pale margin of this area is indicated by an arrow at A in *Fig.* 242; with a portion of healthy-looking tissue it was removed, as in *Fig.* 242, for microscopical examination, as were also pieces from the remote sites marked B and C on *Fig.* 242.

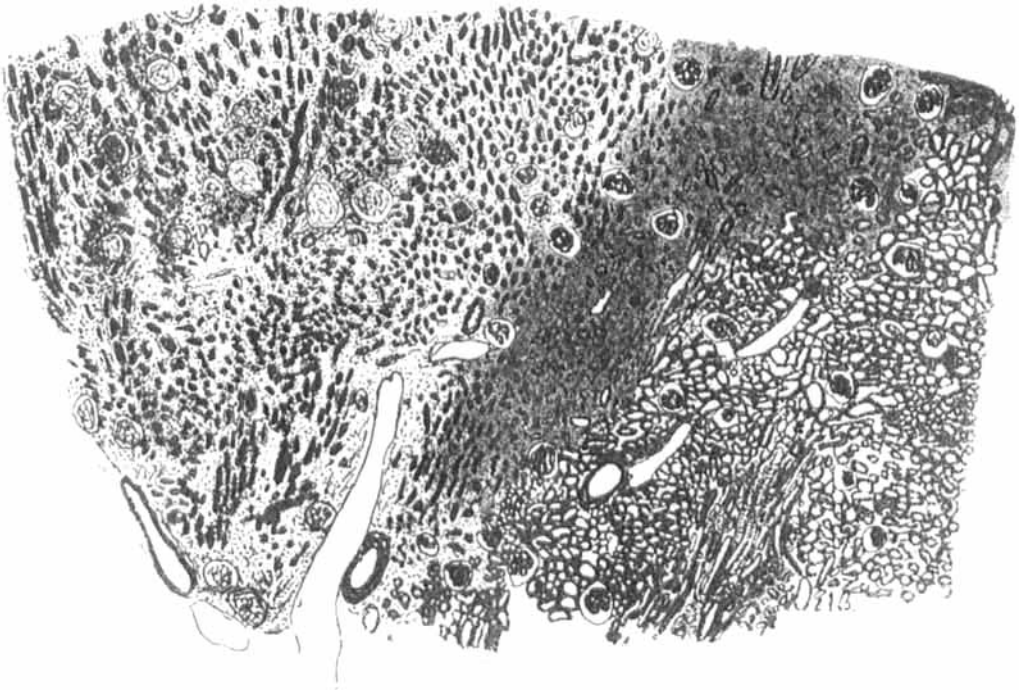

FIG. 243.—Kidney. Section through the margin of the hæmorrhagic discoloration surrounding the track. To the left, degenerated tubules and glomeruli, which have lost all nuclear staining and reproduce the appearances of an anæmic infarct. To the right, an area of healthy kidney tissue. Intervening between the two is a zone showing attempted regeneration of the tubules. The details surrounding the prominent tubule in the area of anæmic infarction are shown in *Fig.* 244, and those of a zone of regeneration in *Fig.* 245. Some of the vessels in the figure have lost their endothelial lining.

The appearances in piece A alone merit detailed description, since the other pieces more remote from the injury presented the appearances of healthy kidney tissue. In this piece (*Fig.* 243), the cortex nearest the injury showed, under low magnification, patches of healthy-looking glomeruli and convoluted tubules alternating with patches where the glomeruli were with difficulty recognizable and the tubules were replaced by seemingly structureless débris. In the boundary and papillary zones there was a corresponding alternation of the healthy with the dead. The appearances where the naked-eye

extension of blood-staining gave a sharp margin with the apparently healthy tissue have been depicted in *Fig.* 243. It will be seen that, while the normal anatomical arrangement has not been disturbed, glomeruli and tubules have both degenerated *in situ.* Both have completely lost their nuclear staining. The capsules of Bowman are devoid of evidence of hæmorrhage or exudate. The glomerular capillaries have degenerated, so that the nuclei no longer stain with hæmatoxylin. The débris replacing the tubules is the degenerated epithelium lining the convoluted and ascending and descending tubules (*Fig.* 244). It shows the appearances of coagulation necrosis, the elements derived from the individual cells (but not their nuclei) being distinctly recognizable. There is no evidence of inflammatory or regenerative processes

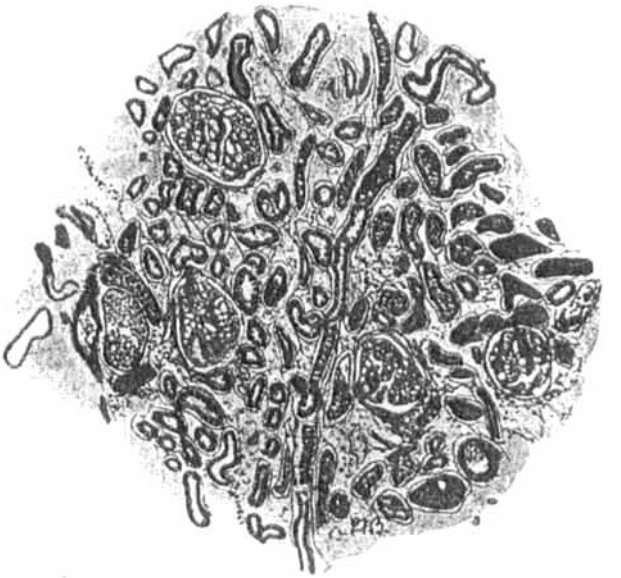

FIG. 244.—Kidney. Details of an area of anæmic infarction. A small hæmorrhage lies to the left of the figure, where are also shown an artery and vein, in the former the endothelial lining is desquamated.

anywhere. The picture is typical of coagulation necrosis as described by Weigert long ago, and well known to occur in anæmic infarction of the kidney. This area is separated from apparently healthy tissue by a narrow zone in which there are many tubules giving evidence of attempted regeneration, as shown by the epithelial proliferation, and in which the glomeruli look quite healthy. An area, selected where the healthy alternated with dead tissue, showed the appearances depicted in *Fig.* 245. The cell outlines of the epithelium in the dead tubules are retained, but the nuclear staining is lost. Some of the glomeruli show proliferation of the endothelium of Bowman's capsule, others a proliferation of the nuclei of the capillaries, while yet others appear normal. In short, the whole appearances are incompatible with a molecular vibration, which must have passed across all the tubules uniformly,

being responsible for the distribution and occurrence of the degeneration. This distribution is compatible with its being solely the secondary consequence of primary injury to the larger blood-vessels, the vascular arches, the stellate veins, and the glomeruli. The patchy distribution of the healthy with the dead tissue in this case agrees also with the occurrence of subcapsular hæmorrhage as described in the first case of injury to the kidney.

The findings in these two cases, therefore, differ in important aspects from those described by Stokes and McNee, who, as quoted by Sir A. Bowlby,[4] state: "The right kidney presented a perforation in its lower pole. A piece

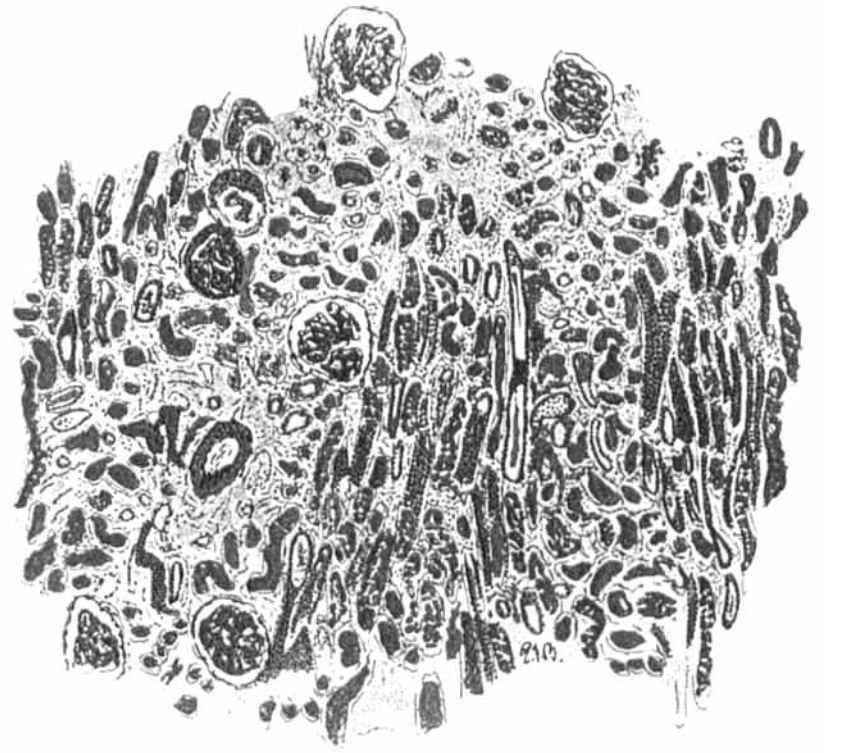

FIG. 245.—Kidney. Details of a zone of attempted regeneration. Dead tubules and glomeruli alternating with living ones. Proliferation of the epithelium of tubules, and of the endothelium of Bowman's capsules. Desquamation of the endothelium of an empty artery, with swelling of its wall.

of kidney was taken from what was apparently a healthy portion of the upper pole for microscopical examination. It was hardly recognizable as kidney. There was present only a fibrous stroma of the tissues, without any of the specific kidney cells, and only one or two glomeruli were recognizable. The tubules had apparently desquamated all their lining epithelium, and in a few of the collecting tubules there was present some granular material, perhaps representing the destroyed cells. The whole section was full of small hæmorrhages, and in places there was a slight infiltration with polymorphs." The figure accompanying their description hardly supports it, for, together with

hæmorrhages, the figure represents kidney tissue, and includes a glomerulus. The epithelium is present, it is separated from the basement membrane of the tubules as it might be by shrinkage when imperfectly fixed and manipulated during preparation from post-mortem material. The figure indeed exhibits an exaggeration of the faults which were also unavoidable in making the preparations of which the figures accompanying this paper are accurate representations. In the tissue near the injury to the two kidneys here described similar appearances are encountered, which are depicted in *Figs.* 240 and 241.

The two specimens described above appear to show that in spite of a gunshot wound of the kidney, a large portion of functioning tissue may remain. Such remote injuries as occur are due to hæmorrhages, situated where they would naturally occur in a parenchymatous solid organ, namely, under the capsule, which might be expected to yield to the pressure set up by the missile, capillary hæmorrhages resulting, just as the stellate fissures running out from the point of impact can be ascribed to a sudden increase of the internal pressure of the spleen and kidney tearing the capsule at weakened points (see *Figs.* 234 and 235). Other remote injuries are secondary, and due to the anæmic condition of the glomeruli and of the tubules supplied by the efferent arteries originating in the areas fed by the larger vessels which were directly injured.

INTESTINE.

The accompanying figures are from a wound of the small intestine, and illustrate what appears to be a common occurrence. The bullet, entering on

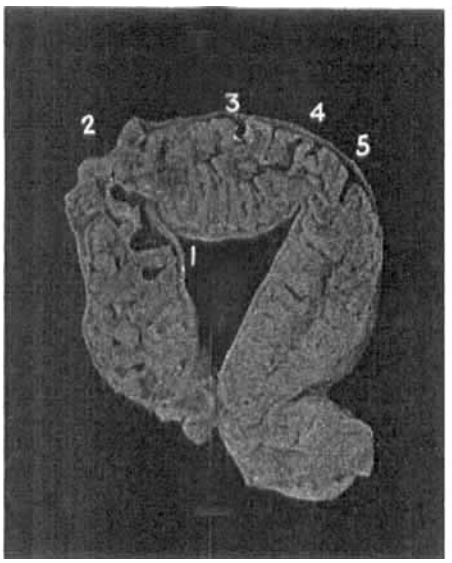

FIG. 246.

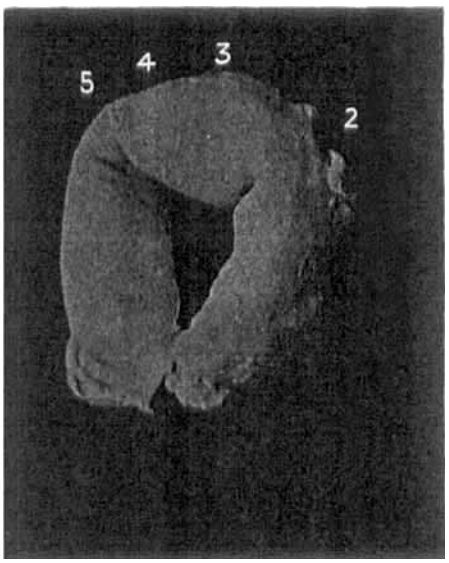

FIG. 247.

FIG. 246.—Small intestine. 1, Hæmorrhage round entrance wound. 2, Hernia of mucous membrane at exit wound surrounded by hæmorrhage. 3, 4, 5, Other hæmorrhages corresponding with injury to the peritoneal surface seen in *Fig.* 247.

FIG. 247.—Small intestine. Three abrasions of the peritoneal surface, corresponding to the hæmorrhages seen in *Fig.* 246.

one side of the canal, has made the large exit wound seen in *Fig.* 246 at 2, with hernia of the mucous membrane, on the opposite side. The wound of entrance was surrounded by hæmorrhage (*Fig.* 246), most marked beneath the inner and outer muscular coats. The villi had also a rosy tint in this neighbourhood. There was similar hæmorrhage on one side of the wound of exit, while on the other side, in addition, three smaller hæmorrhagic areas were present, the most remote being about three inches from the hernia, and separated by apparently healthy tissue (*Fig.* 246). These latter could not, however, be ascribed to action at a distance. They correspond with three injuries on the peritoneal surface (*Fig.* 247), in two of which loss of tissue, not obvious to the eye, was revealed by the microscope. These injuries were in all probability due to the contact of the missile in passing, or to nipping up of the intestine by direct violence. The villi showed no departure from normal, except in the immediate track of the missile.

BLOOD-VESSELS.

The secondary effects resulting from injury to vessels have been already illustrated in the case of the kidney They are also of great importance in relation to injuries to muscles. This is well seen when the blood-supply of a long muscle of a limb is destroyed, as contrasted with the effect on such muscles as the rectus abdominis, or the long muscles of the back, where there is a ready and abundant segmental supply.

This subject will be referred to in another paper on the bacterial invasion of 'gunshot' injuries of muscle; but it may be pointed out here that the extensive secondary impairment, or death, of the muscle which results, is a main factor in promoting the extension of bacterial invasion as seen in the limbs—e.g., in the muscles of the front and inner side of the thigh. Similarly, the limitation of the area of secondarily degenerating muscle is a main factor in the rarity of the gas in phlegmonous gangrene, and in extensive bacterial invasion generally of the muscles of the abdominal wall, flank, and back.

The injuries of vessels have been studied in a number of cases, more particularly by following the disturbance of the elastic lamina. They may be illustrated by a case which was not investigated in the first place for this purpose, but to elucidate the way in which an open passage was made and maintained between the femoral artery and vein. The sections were therefore not studied with a view to ascertaining whether there was only one injury, and preoccupation with other aspects led to the tacit assumption that there appeared to be also injury at a distance, in accordance with widely-held views. A bullet had passed between the femoral artery and femoral vein, injuring their contiguous walls, so that a true aneurysmal varix had formed, without an intervening sac. When the injured portions of the vessels were removed five days later, by Capt. Fraser, the torn walls of the two vessels were united so as to adhere on one half of the circumference of the passage between them. This union was effected in part by means of an intervening portion of tissue derived from the displaced adventitia of the artery. The attention given to the nature of this intervening piece led to the tacit assumption that a piece of sound vein wall separated the track of the missile from a remote second injury

to the vein wall. Re-examination of the sections mounted in series has shown that this appearance is due merely to the irregularities of a single transverse wound in the vein wall, from which there extended an irregular fissure for about three-quarters of an inch in its long axis.

The limited nature of the disturbance is sufficiently shown by the arrangement of the elastic membranes and fibres in the accompanying diagram (*Fig.* 248). In the present connection, the only microscopical appearances of

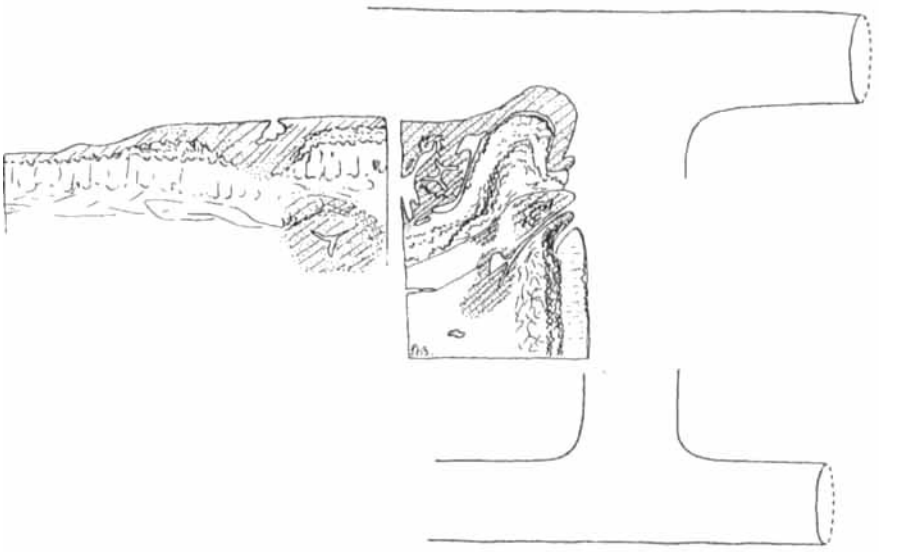

FIG. 248.—Diagram of injury to femoral artery and vein. The injured walls of the artery and vein are everted so as to form an almost continuous tube, and from this transverse injury a slit runs axially along the vein wall for three-quarters of an inch, so that the gap in the endothelial wall, if seen *en face*, would resemble a very rough and ragged-edged nail. One of the ragged projections from the slit is seen to the left of the diagram, and from it a hæmorrhage extends downward in tangential section. In a series of sections this hæmorrhage becomes continuous with that shown on the right of the diagram (see text).

Continuous black lines on surfaces and enclosed spaces = Endothelium. Wavy lines = Elastic lamina and fibres of vascular coats. Cross-hatched and dotted areas = Organized clot covered with endothelium. Vein above, artery below.

interest were the formation of clot in the fissures in the vein, thickening of the subendothelial layer of the intima of the artery, limited disturbance of the elastic lamina, and the occurrence of proliferation of the endothelial lining of the artery and vein, most marked in the latter, from which it had extended over the injured surfaces, thus showing that there had been no action inimical to the processes of healing on the endothelial cells bordering the edges of the wound.

SUBCUTANEOUS TISSUE AND APONEUROSIS.

The effects of injury on the elastic fibres has been studied in the subcutaneous tissue, and here also the disturbance is limited to an area immediately surrounding the track of the missiles. The capillaries in such an area are found, as in the accompanying figure (*Fig.* 249), to be perfectly capable of the

well-known congestion so essential to and characteristic of early inflammatory change. In the case illustrated in *Fig.* 249 they were not only dilated, but were crowded with leucocytes, showing that, far from bieng greatly injured, they were capable of supplying the requirements of inflammation right down to the injured surfaces.

FIG. 249.—Subcutaneous connective tissue, areolar tissue, and fat, showing track of shrapnel. Dense connective tissue to right and above, which is disorganized and filled with hæmorrhage around the track. On the left, and abutting into the track, the capillaries between the fat cells are widely dilated and filled with leucocytes, in places so densely packed as to produce the dark patches seen in the areolar tissue. The intense black spots represent emplanted wool-fibres (khaki). Entire area removed at operation twenty hours after injury. Compare *Fig.* 250.

Five days after wounding, an examination was made of the aponeurosis covering the origin of the deltoid muscle, through which a bullet had passed so as to destroy the head of the humerus and pass out behind. The great cellularity of the dense connective tissue around the track, and the occurrence of columns of cells, were most striking, as was also the proliferation of new capillaries and of the sarcolemma nuclei of the muscle insertions. There could be no question of a zone of dead tissue surrounding the track of this missile of high velocity.

MUSCLES.

The examination of injured muscle has been a daily occupation for eight months, but it is only proposed to consider here whether the injury is localized

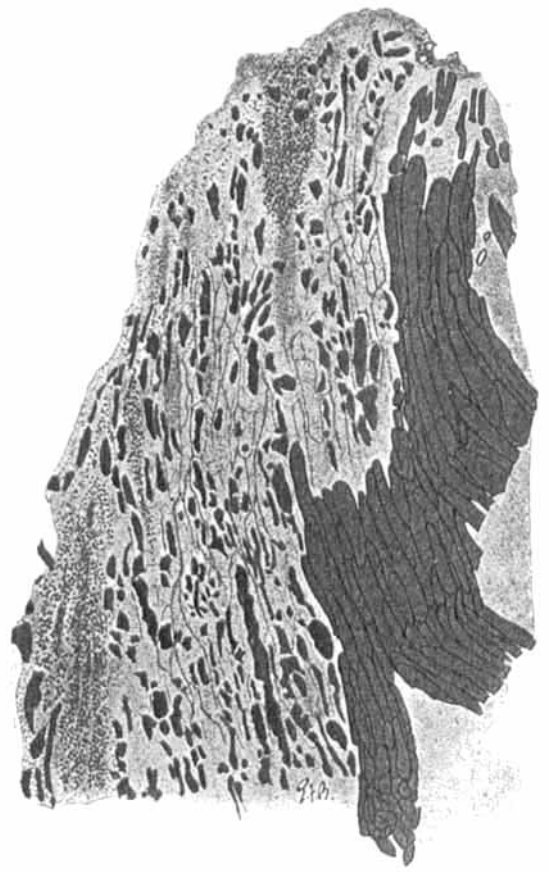

FIG. 250.—Portion of muscle lying beneath dense connective tissue seen in *Fig.* 249. The muscle fibres to left of figure have been immediately killed by the violence of the missile, and are sharply delimited from the living muscle fibres, some of which show a proliferation of the nuclei of the sarcolemma. To the right, limit of surgical incision into healthy muscle. Twenty hours after injury. Compare *Fig.* 251.

to the track of the missile, or has also remote and important consequences. The conditions found have been so constant, that they are sufficiently

illustrated by two examples representing the early and the late changes respectively. *Fig.* 250 illustrates the appearances of a piece of muscle which lay immediately subjacent to the dense connective tissue seen in *Fig.* 249, through which shrapnel has passed and fractured the tibia, in which it was embedded. A narrow zone of muscle fibres lining the track is dead and disintegrated. The sarcolemma nuclei are nowhere stained by hæmatoxylin. The dead are sharply defined from the living muscle fibres, the latter presenting only an unusual appearance in places where excessive numbers of sarcolemma nuclei are apparent in the fibres nearest the track. The sharp distinction seen under the microscope was not evident to the naked eye of either the surgeon or the pathologist; but the surgeon had succeeded in his effort to remove the injured part by cutting into sound muscle, even if the margin appears slight, as the subsequent course of the wound showed.

FIG. 251.—Muscle fibres adjoining those killed by direct violence, to show proliferation of the nuclei of the sarcolemma, advanced in one fibre, abortive in another, and irregularly distributed in the rest of the fibres. Marked longitudinal striation and loss of cross-striation. Twenty hours after injury.

In another figure (*Fig.* 251), the appearances in the muscle fibres adjacent to those killed by the missile, in a similar injury, are shown under higher magnification. Longitudinal striation is unusually marked, and the transverse striation is not evident. Two fibres are shown in which the proliferation of the nuclei of the sarcolemma has proceeded to the formation of almost solid tubes of cells, more perfectly in one case than in the other; but there is no other evidence of injury leading to regeneration. There is a somewhat wide separation of the muscle fibres, which may have been produced partly by the preparation of the material.

Lest these changes might be the precursors of others only showing themselves later, as in injuries of the kidney, muscle has been frequently examined at various intervals after wounds had been received. In them the sharpness of the margin of injury is most striking. *Fig.* 252 shows the track of a missile through the muscles of the lumbar region; it might almost have been made by a trochar. *Fig.* 253 shows a portion of the same preparation under higher magnification, from which it is seen that only a narrow marginal zone of the muscle fibres has been called upon to take part in the processes of repair, the injury might be no less had it been produced by a sharp knife.

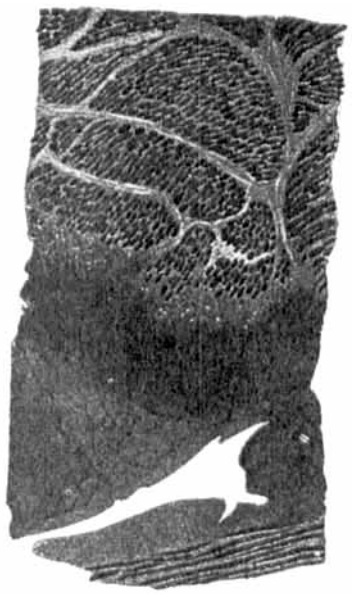

FIG. 252.—Muscle of lumbar region, showing track of bullet which fractured vertebral column and produced death after eight days. Old hæmorrhage and fibrin around track, and above and below it sharp delimitation of injury. In this case there is no hæmorrhage into the intramuscular septa, nor evidence of proliferation of the nuclei in the septa, such as has been observed occasionally in other cases.

Long muscles have been cut in continuous sections from the wound track to their insertion or origin, at distances of six inches and ten inches in two extreme cases, but no remote primary consequences have been discovered, nor have any late effects, such as necrotic changes, fractures of muscle bundles, or hæmorrhages at a distance, been observed. The extent of the injury to long muscle is to be measured, not by a line vertical to the axis of the track of the missile, but by the extensive surface area comprised in it or produced by the loss of tissue.

In the case of some injuries to the muscles of the back, hæmorrhage has been observed in the septa shown in *Fig.* 252, but it only occurred in those nearest to the wound, not more than half to three-quarters of an inch away.

The secondary consequences of anæmia of muscles, due to the severance of vessels or thrombosis, have commonly been observed, but they do not come into the category of the special characteristics of gunshot wounds, they will be referred to in a paper on the bacterial invasion of gunshot injuries of muscle.

Although the obvious local effects of 'gunshot' wounds may sometimes be surprisingly extensive in their ragged ramifications, the foregoing observations show that remote and other far-reaching effects are by no means universal. Indeed, during eight months of close attention to so important a subject, I have failed to find any evidence that they occur at all in the organs or tissues examined. If vibration be set up by the projectile in the tissues of the body, it does not result in capillary hæmorrhages, except in situations where they would be expected—for example, under the capsule of the kidney; and remarkable disintegrations of cells—or even injury of any sort at a considerable distance from the obvious site of the injury—have not been met with.

The heavy infection of tissues by bacteria, effected by the passage of projectiles, would of itself serve to shake any belief in vibration being an efficient cause of cell-death, apart from the influence of direct violence. The bacterial invasion of injured tissues will be considered in another paper, here it suffices to point out that the facts set out above are all in favour of conservative surgery in 'gunshot' injuries. By a too extended removal of tissues

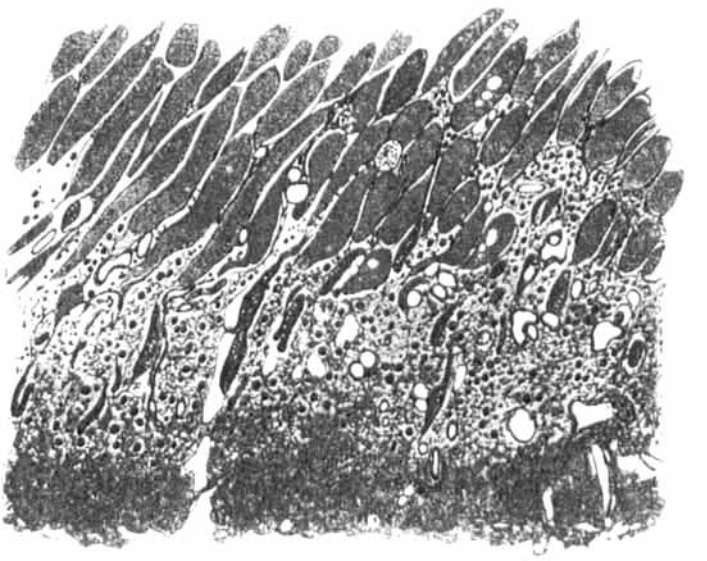

FIG. 253.—Muscle of lumbar region. High-power view of line of regeneration after injury to muscle fibres (on extreme left of *Fig.* 251). The sharpness of the line of demarcation of the healthy from the injured tissue is very striking.

adjacent to the injury, the gap which has to be filled may often be made needlessly great, and the duration of the period of recovery needlessly increased, leaving out of all consideration other possible contingencies.

Figs. 237, 238, 239, 240, 251, 252, and 253 were drawn for me by Mr J R. Ford, with his accustomed skill and accuracy, the other figures have been made by myself.

REFERENCES.

[1] *Brit. Jour of Surg.*, 1915, iii, No. 9, 118.
[2] *Ibid.*, 1916, iii, No. 11, 461
[3] *Ibid.*, No. 12, 647
[4] *Ibid.*, No. 11, 460.