

On the pathology of shock / read December 1879 by C.W. Mansell-Moullin.

Contributors

Mansell-Moullin, C. W. 1851-1940.
University of Oxford.

Publication/Creation

London : H.G. Saunders, 1880.

Persistent URL

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With the Writers (sup) 14

ON THE PATHOLOGY OF SHOCK.

A DISSERTATION FOR THE DEGREE OF M.D.

Read December, 1879,

BY

C. W. MANSELL-MOULLIN, M.A., M.D., OXON., F.R.C.S.;

FELLOW OF PEMBROKE COLLEGE, OXFORD;

LATE RADCLIFFE'S TRAVELLING FELLOW OF THE UNIVERSITY;

SURGICAL REGISTRAR TO THE LONDON HOSPITAL;


FORMERLY HOUSE SURGEON, HOUSE PHYSICIAN, AND ASSISTANT-CHLOROFORMIST

TO ST. BARTHOLOMEW'S HOSPITAL, LONDON, E.C.

LONDON

H. G. SAUNDERS, MACHINE PRINTER, CAROLINE PLACE, BAYSWATER.

1880.



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P R E F A C E.

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THE subject of Shock has from the earliest period been one of the deepest interest to all concerned in the progress of surgery; and perhaps at no time more than at present, when such questions as the influence of anæsthetics in preventing its occurrence, and their effect during its continuance, are continually brought before our notice.

That during the time I passed at St. Bartholomew's I witnessed many cases of the more ordinary types, and some that, from the circumstances under which they occurred, deserve a more permanent record, must be my excuse for attempting a subject acknowledged to be one of the most difficult and obscure in surgery. One of these rarer and more simple cases I have detailed at length at the commencement: then I have given a brief account of the more ordinary forms, comparing them with cases of syncope; and have proceeded to examine the theory originally put forward by Goltz; this, which has generally been received as a fair and reasonable explanation, I have endeavoured to show is insufficient, on the ground that it fails to account for the magnitude of the changes, and that, from the interdependence of all parts of the mechanism of the circulation, it is not possible to act on one without influencing the rest. I fully agree with Goltz that shock is due to the power of

inhibition, inherent in nerve centres; but I have attempted to show that, to produce the effect, this power must be exerted at least on all of those that control the blood pressure, if not indeed on others as well, which might, if the more limited view be regarded as correct, be influenced secondarily through the circulation; but the question of the extension of inhibition over other organs than those concerned immediately with the circulation is one only to be settled by the accumulation of observations and the use of other methods of investigation.

In addition to the references given elsewhere, I have to acknowledge my indebtedness to Dr. Lauder Brunton for his papers on "The Pathology and Treatment of Shock and Syncope," and "On one of the Causes of Death during the Extraction of Teeth under Chloroform;" and to an article by Fischer on Shock, in Volkmann's Series.

ON THE PATHOLOGY OF SHOCK.

FREDERICK W—, aged 49, a shoemaker by trade, was admitted into Mark Ward in June, 1879, complaining of a swelling in the abdomen, which, though only noticed for the first time about ten months previously, had now become such an inconvenience from its size that he could no longer follow his occupation. In general aspect he was short and slightly built, with a somewhat miserable expression of countenance, though he seemed, to all accounts, to have enjoyed fairly good health, and never to have suffered from any specific disorder or from intemperance. His thorax, though not well made, even for a man in his occupation presented, on physical examination, nothing abnormal, with the exception of the line of hepatic dulness, which was somewhat raised; but the abdomen was greatly distended, evidently by a tumour connected with the liver, extending far beyond the limits of the epigastric and right hypochondriac regions, nearly down to the umbilicus in the middle line, and to the spine of the ilium at the side—firm, smooth, rounded, and absolutely dull, without a trace of fluctuation, or of hydatid fremitus. So far as could be ascertained, the other abdominal organs were not affected; the spleen did not seem to be enlarged; it is true there was a trace of ascites, but not more than might have resulted from the pressure of such a mass: there was no history of icterus, nor was there any albuminuria, though the specific gravity of the urine was below normal. After a stay in the hospital of about a month (during which there was a material improvement in appearance and increase in weight) it was decided, as there was no doubt about the diagnosis, to adopt some further and more radical measure, the patient himself being particularly anxious that something should be done, as the swelling, which was slowly but steadily increasing in size, totally precluded his carrying on his trade.

Accordingly, on July 18th, about three hours after the patient's lunch, a small incision was made through the skin over the main prominence of the tumour, a little below and to the right of the xiphoid cartilage, and a fine aspirator trocar and canula introduced, with the result of obtaining immediately about two drachms of a clear limpid fluid. When no more followed, it was conjectured that some hydatid membrane had blocked up the canula; so it was drawn out, and a larger one, perhaps the size of a small goose-quill, introduced through the same puncture, without the patient making the least complaint of pain or flinching to the smallest extent. But as the post-mortem examination showed, this one missed the cyst and entered the liver substance; so that the two or three ounces of fluid that escaped through it consisted of nearly pure blood, which coagulated readily. While this was happening, and owing to the suction of the aspirator and the size of the canula, it required but a very short time, a sudden change was observed to pass over the patient's face: the canula was instantly withdrawn; but from one moment to another, without warning of any kind, without a cry or struggle, all expression vanished from his countenance: a naturally bright complexion faded into a livid pallor; his arms sank down by his side, and the pulse ceased, with the exception of a few faint beats, that seemed to coincide with a short and gasping attempt at respiration. So sudden and unexpected was the occurrence, that, although the remedies ordinarily employed under similar circumstances were actually on the spot, none could be applied.

At the post-mortem examination, performed twenty-four hours after death, the following notes were made:—Temperature cool, though it was the month of July; rigor mortis well marked; body not remarkably pale; the superficial veins on hands and arms being even distended; no trace of any such blanching as would have resulted from internal hæmorrhage. On laying open the abdominal cavity, in which was a slight amount of ascitic fluid, just blood stained, the puncture made by the trocar was seen on the convexity of the right lobe of the liver; and a probe, on being passed into it, was found to enter a small cyst, covered by perhaps half an inch of normal liver tissue, lying by the side of one much larger, and full

of daughter cysts. The trocar did not seem to have penetrated further, or to have entered any other part of the liver. There was no marked distension of the abdominal vessels.

The right auricle of the heart was opened in situ under water; it contained no air, only a small coagulum; the pulmonary artery was quite free, and the muscular tissue healthy. Fluid injected down the inferior vena cava from the thorax against the direction of the blood-stream, could be made to escape through the puncture in the liver with considerable freedom, but no vein of any size was found to have been injured.

The other viscera presented nothing abnormal, with the exception of a small cyst in the spleen, and a granular condition of the kidneys, which had been suspected during life, owing to the low specific gravity of the urine.

I have entered into the particulars of this case at considerable length partly on account of its rarity, but mainly because it seems to me to be a thoroughly typical example of sudden death from the influence of shock, uncomplicated by the addition of any extraneous circumstance. The operation, although one never to be undertaken lightly, contained in itself nothing that in the ordinary course of events would have produced such a result: there was no loss of consciousness or sign of syncope: the pain was not severe; the patient did not even flinch: there was no anæsthetic to introduce an additional element of uncertainty: the patient had never suffered from any illness beyond the local trouble; and although possibly not the subject one would choose as a type of rude health, or as more fitted than another to withstand a severe operation, yet, post-mortem, no viscera but the kidneys were found to be diseased; and certainly there was no lesion to which, on even the most rash hypothesis, the result could have been attributed.

It is not absolutely unique, for a like result in a very similar case has been recorded by Mr. Bryant in the course of the past year;* and it has been stated that such

* *Lancet* June 8th, 1878.

accidents are by no means unknown in Iceland, where, owing to the imperfections in the sanitary arrangements, hydatid disease is so common. Mr. Bryant's case differs from the one I have described in a few particulars, which, though not unimportant, are scarcely sufficient to necessitate a separate account: the amount of fluid removed was considerably greater, about nine ounces, though much more than this has frequently been withdrawn without damage; and, while the inferior vena cava was considerably obstructed by the pressure of the tumour, a large branch of the portal vein was perforated by the trocar,—a condition which may have seriously interfered with the passage of the blood through the abdominal viscera to the heart.

Nor are the records of experimental pathology devoid of similar examples; for it rests on unquestionable authority that, occasionally, without any warning or apparent reason, so simple a procedure as drawing forward the stomach of an animal to attach it to the abdominal wall, in the attempt to establish a gastric fistula, is followed by immediate collapse and death. But it is very singular that, if we exclude those cases in which the fatal result follows only after a period of reaction, there should be no single well-authenticated case in man of sudden death consequent upon a simple blow on the abdomen, without apparent injury to any of the subjacent viscera; and this, in spite of the generally-received tradition on such matters, and the undeniably grave symptoms which are so notoriously produced. Even the classical instance given by Sir Astley Cooper, and always quoted as an example, of the labourer who, while wheeling a barrow, received a slight blow in the epigastrium and fell down dead, cannot be admitted,* though it is supported by such authority; for it did not occur within his own practice, and in the account left of it there is nothing that is inconsistent with the idea of sudden failure of the heart's action from the combined effects of degenerated structure and excessive exertion.

But while this extreme form is so uncommon that its very existence is only admitted, and requires definite proof, there may be seen every day in the practice of a

*Pollock. Holme's System. Injuries of Abdomen.

large hospital cases equal in the interest they excite, and no less grave in the matter of prognosis, differing in this, that unless the injury is of itself so severe as to be inconsistent with the continuance of life, the fatal result does not supervene till after the lapse of some, often a considerable, period of time. And they would be still more common if it were admissible to include those instances in which symptoms of reaction, or of more or less imperfect recovery from the immediate effects, have made their appearance. Here, however, the question has become complicated by the addition of some other cause, such as hæmorrhage, or fatty embolism, or septicæmic collapse from the rapid absorption by some large serous surface of an irritating material, or some other of the numerous possibilities of surgery, sharing the responsibility of the result, and rendering hopeless the due allotment of the symptoms.

Few conditions are more characteristic than that of a patient suffering from the graver effects of shock; fewer still present a closer resemblance to death itself: the livid pallor of the skin, with a cold, clammy sweat hanging on the forehead and eyebrows; the vacancy of the half-closed eyes, which seem to sink into the orbits, and the total absence from the face of all expression, often even that of pain, are such as perhaps are never met with short of death itself; and this resemblance is all the more striking as the patient lies unmoved by anything that takes place around him, with limbs helpless by his side, as they were placed or fell of themselves, just as if all sensation and power of motion had gone for ever; but still a paroxysm of pain more fierce than usual, or the urgent repetition of a request, is able to elicit an almost inaudible voice, or the slow execution of some half-finished movement. Often the pulse is too rapid to count; sometimes so faint and feeble as not to be felt; the respiration generally shallow and irregular, with an occasional gasping sigh; and the temperature fallen so low, in spite of all attempts at external warmth, that one often doubts the truth of one's own observation.

At other times again, in place of this death-like quiet or succeeding to it, is a condition of the most extreme restlessness and excitement, when the patient tosses

wildly and vaguely from side to side, as one frantic, groaning and screaming, or shouting again and again the same sentence, perhaps utterly meaningless ; totally regardless of the pain he inflicts on himself, seemingly conscious, but yet so preoccupied with one all-absorbing idea, often that of impending death, that no response can be obtained from him. And then not unfrequently from one instant to another this condition passes into one of extreme prostration, which comes rapidly to a termination. But it must be noted that however unlike the former these symptoms may be in outward appearance, there is nothing improbable in the suggestion that in reality they represent different degrees of the same pathological condition ; for either seem to be capable of succeeding to the other, just as coma and convulsions not unfrequently alternate, or even under some circumstances occur simultaneously. There is, too, the most complete uncertainty as to the influence the kind of lesion, or the constitution of the patient, may have in giving rise to one or the other ; only it has seemed to me that the second type, which I have seen supervene equally after accidents of the head, thorax, and abdomen, seldom occurs unless the amount of damage inflicted is great in extent, independently of any other feature which may add to its gravity.

Syncope, on the other hand, presents a most striking contrast to this in its simplicity and uniformity. Whatever may have been its ultimate cause, whatever its termination, as the name suggests, it offers one characteristic feature, a cutting short of those processes which, according to general belief, it is the function of the cerebral hemispheres to carry on : the other structures of the brain, especially those concerned in the regulation of the processes which immediately subserve animal life, may be affected, but unless from long continuance or unusual severity the case has a fatal termination, they never are to the same extent. When this does happen, it becomes almost impossible to distinguish shock from syncope ; and indeed, since the one, as I hope to show later on, is, in its more rapid form, due to a sudden check affecting the whole circulation ; while the other is produced by its stoppage in one single organ, it is manifest that there is nothing incompatible in the simultaneous occurrence of the two ; and that it well might be that those fatal cases of syncope

due to intense emotion, fear, or joy, are in reality to be ascribed to shock, complicated by syncope as an accessory. That the latter is not essential is clearly shown by the case the details of which I have given at the commencement ; here there was no apparent emotion of any kind ; there had been a decided wish expressed ; throughout the whole operation there was no complaint of pain ; the symptoms sudden as they were did not come on till near the end ; and, as was remarked at the time, the patient's face was not so much pale as livid.

It is scarcely necessary to bring forward at any length evidence to prove that in syncope the anæmia of the cerebral hemispheres is the pathological condition that underlies the symptoms. There is no anatomical difficulty in the explanation ; the cranium is no longer regarded as a closed cavity which must receive each instant the same amount of blood that it loses ; those instances of deformity or accident, in which it has been possible to investigate the conditions of the arachnoid space in the spinal canal, have shown most incontestably that it has communication with the intraventricular cavities sufficiently free to enable the greater or less arterial pressure within the cranium to receive immediate compensation ; and it would indeed be strange if the striking pallor of the face, generally the first symptom observed, were not attended by a change in the same direction, affecting the deeper structures. A consideration of the simpler and more easily understood causes which can produce it points directly to the same conclusion ; for example, when, through ignorance of all the ordinary principle of nursing, a patient in the later stages of a protracted or wasting disease is allowed to sit up suddenly ; all colour at once leaves the face, and a fainting fit comes on, soon recovered from if proper measures are adopted, but fatal equally soon if the same position is allowed to be maintained. In such a case there can be no room for doubt as to the actual state of the brain, no matter what may be the immediate cause of the deficient supply of blood it receives ; whether it arises from the extra labour thrown on an already enfeebled heart, and the actual increase of weight in the blood-column of the carotids, which can receive no compensation from the side of the veins ; or from a cause which Lister has pointed out, and to which

he has attributed great importance, viz., the sudden action of the vasomotor nerves on even large vessels which is called into play when a limb or any other part of the body is suddenly raised from a horizontal to a vertical position.

Astley Cooper, too, by deligating the vessels that supply the brain, and Flemming by compressing them, have shown that the local change is the immediate cause, and naturally the same explanation may be extended to those cases where, without there being any actual obstruction, an unequal distribution in the amount of blood is caused by some of it stagnating in a distant part of the circulation, as after a prolonged hot bath or in a crowded room, and to those also where syncope results from not a relative diminution, but an actual one, affecting this organ only in common with the rest of the body.

Shock, on the other hand, however severe the degree of nervous depression by which it is accompanied, never presents such a train of symptoms as could result from the implication of a single organ: the change that has taken place, whatever it may be, seems to be universal and uniform in its distribution: all parts of the body appear to suffer alike, and very nearly in equal proportions: whatever structure is examined there is invariably found to be a lessening of its normal functional activity: the life of each part, its energy, and the amount of blood circulating through it, seem to have been reduced to a minimum. Even when there has been no actual loss of blood, the livid pallor and coldness of the skin, the diminution of sensibility, the sluggishness of the cerebral functions, the lessened vigour of contraction and readiness to respond to stimulus shown by the muscles, the rapidity, smallness of volume, and compressibility of the pulse, and the partial suppression of the secretions, can point to nothing else than a general failure in the capillary circulation, such as could only result from an equally general fall in the arterial pressure. What the cause of this may be, and how it produces such effects, are the fundamental questions that underlie the pathology of shock.

It is to Goltz * that we are indebted for the generally

* Virchow's Archiv, xxvi. and xxix.

received explanation, and especially to a series of experiments by which, now some years ago, he showed that contusions of the abdominal wall, and still more of the viscera, produce two most striking effects on the circulation, of which sometimes the one, sometimes the other is, in the frog at least, the more prominent. The first was the immediate arrest of the heart in diastole; and the absolute dependence of this on the integrity of the nervous system was proved most conclusively by repeating the experiment, either when the animal was thoroughly under the influence of an anæsthetic, or when either the vagi or the splanchnic nerves were interrupted: under these circumstances this result never followed; the second, less conspicuous, but more permanent in its effects, and equally serious, was the extreme distension of the vessels of the abdominal viscera, not arterioles only, but venules and veins as well: so that when the heart did resume its function, so long as the frog was held in the vertical position, no blood could reach it, and it remained pale and half transparent, as it contracted slowly and laboriously; like the former, this was dependent on the nervous system, and especially on the splanchnics. The combined effect of these was to produce an anæmia of all the rest of the body, comparable only to that which results from severe hæmorrhage, and from this the remaining symptoms naturally followed.

To all appearance this experiment is complete in itself, and the explanation it offers has been very widely received as reasonable and sufficient. The facts are beyond dispute; and when once the veins and venules had been shown to be under the control of the vasomotor system as much as the arteries, and when it had been stated that the abdominal venous system alone was sufficiently capacious to contain all the blood in the body, the rest followed almost as a matter of course; as soon as the state of tonic contraction, which is normally maintained by the muscular wall of the vessels, had been taken away by some influence reflected down the splanchnic nerves, the calibre became very much increased, and, there being no longer any pressure on the contents, the blood stagnated in them, and a hæmorrhage into the intestinal vessels took place, no less fatal than if it had been external, for by it the blood was withdrawn

from the general circulation quite as effectively; and then the arterial pressure fell below the point consistent in a warm-blooded animal with the maintenance of its life; in a frog, after the heart had had sufficient time to recover, laying it in a horizontal position, at once enabled the blood to fill the auricle, and recommence its circuit: in the mammal stoppage of the heart's action was immediately fatal, as in the more rapid forms of death by shock: its weakened action and the accumulation in the abdominal vessels would account for the symptoms of the more common type.

But finished and satisfactory in appearance as this theory is, there may it seems to me be certain reasons urged against it which are fatal to it so far as its completeness is concerned; though there can be little doubt that it is one stage, and a very long one, on the road towards solving the difficulty. The first point is that the symptoms of shock are not quite the same as those of hæmorrhage, as they almost necessarily would be if this were the case; though it must be admitted that the two so often occur together, and the addition of even a slight hæmorrhage under these circumstances is so grave an accident (for the loss of a very trivial amount may prove instantaneously fatal in the presence of a low arterial pressure*) that little more than a general statement to that effect can be made. But it may be urged with more effect that in such obscure pathological conditions it is very rash to draw analogies between the consequences of the same injury in animals, which differ, not only to such an extent in the development of their whole nervous system, but also to no less degree in the relative importance and activity of its various parts; indeed, it might be said with almost as much probability that the condition so induced in a frog is not one of shock at all, and that the dilatation of the abdominal vessels is an incident, occasional it may be, of syncope. While proof of this might be adduced in the remarkable rapid recovery from fainting which patients make when, being placed in a sitting position, the head is forcibly bent forwards and downwards till it rests between the knees. Certainly here gravity can have very little influence on the short blood column between the brain and the heart; and

*Tappeiner. *Ludwig's Arbeiten*; Leipzig, 1872.

it might well be argued that the real agent is the compression of the abdominal viscera, driving the blood to the right side of the heart. Further, it cannot be regarded as otherwise than singular that such marked congestion of the abdominal viscera as must ensue from the accumulation within their vessels of at least four-fifths of the amount of blood contained in the body should so seldom have been noticed in the numerous pathological observations that have been made on fatal cases. Moreover, as active dilatation of the walls of the blood vessels is, from their structure, impossible, it would follow that paralysis of the nerves which govern their muscular coats would allow the maximum expansion to take place under the centrifugal pressure of the blood column; and most of all would this be so when the heart is acting with its full vigour, and sending all the blood it receives into the arterial system with a force in marked contrast to the feebleness exhibited during the continuance of shock; and yet it is found that after section of both splanchnic nerves, though the highest distension results, so far is the arterial pressure from falling to a point inconsistent with the maintenance of life, that animals, in which this operation has been performed, may make a perfectly good recovery;* the local independent centres assuming the functions which the central nervous system is no longer able to carry on, and the vessels gradually recovering their normal calibre and regular tone. Nor is it possible to explain this by the assumption that in shock both local and central mechanisms are paralysed, while after section of the splanchnics, only the latter is taken away and rendered powerless; for if these structures maintain towards each other here the same relation that holds good between them in other parts of the body, the section of the main nerve is followed by such consequences that the local centres along its course present no manifestation of activity whatever for some considerable period; just as after section through the spinal cord, no reflex movements can be excited for some time in any nerve that is dependent on the distal severed portion.

The objections are not supported merely by the naked-eye estimate of the amount of blood contained in the abdominal viscera; nor on the fact of the survival of the

* Asp. Ludwig's *Arbeiten*, 1867.

animals on which the experiments had been performed. Accurate estimates* have been made by numerous observers on dogs as well as on rabbits; on the one hand, of the amount of blood proportionate to the body weight an animal can lose without actually bleeding to death (and even in cases of shock that are not fatal, the anæmia, if it be the cause, cannot be far short of this); and on the other, of the fall in the arterial pressure after paralysis of these nerves: and it has been shown beyond question that although there is considerable difference in individuals, for when the original tonic contraction is feeble and the pressure low, the change is relatively greater (just as it would be in the case of hæmorrhage); yet the alteration in the tension after section of the nerves never is equal to that which ensues on a loss of blood that is nearly fatal, and in the great majority of instances is not half so great.

Again, it is very far from clear that the vessels that form the portal circulation, even in those animals that possess relatively large abdominal viscera, are of capacity sufficient to accommodate the large quantity of blood that must be withdrawn from the general circulation if the pressure is to be reduced to the lowest point that is consistent with life. By placing a ligature on the portal vein, and then estimating the amount of blood contained in its radicles, Tappeiner has shown that it never exceeds sixteen per cent. of the whole quantity contained in the body, or a proportion bearing a relation to the body weight of less than one per cent.; while generally speaking a rabbit will stand a loss three times as great without succumbing. Of course it may be objected that, even though the portal vein becomes so tense that the blood spurts out from a prick made in it as it would from a large artery, the vessels do not contain as much as they would if the nerves supplying their walls were paralysed; but in the figures given above there is ample room for such allowance without endangering the conclusion. It is true that this experiment invariably proves rapidly fatal from the fall of arterial tension which accompanies it; but it cannot be said that this is due to the withdrawal from the general circulation of as little as sixteen per cent. of the total amount of blood; nor is it caused by

*Asp. loc. cit. Tappeiner loc. cit.

paralysis of the heart, for though the pulse wave falls soon after the ligature is tightened, it shows no sort of relation to the other phenomena of portal occlusion, and should rather be regarded as the consequence of the deficient supply of blood received, for it rises again as soon as a fair quantity can reach the central organ. Moreover every slight pressure on the body, and every spasmodic movement, cause the mercury in the manometer to rise again temporarily; so that there are still pathways to the heart left open to the blood. In short, this experiment presents an example of loss of arterial tension, commencing at once, not due to storage in an outlying part of the circulation, or to paralysis of the central organ, yet rapidly proving fatal by its influence on the nerves of the heart and the vessels, which are as dependent on it for their life as are those that govern sensation or motion.

Pathological examples in illustration of this are not wanting: it is true there is no case on record of any simultaneous lesion of both splanchnic nerves; but in injuries to the spinal cord above the first dorsal nerve instances may be found even more remarkable; for not only are the visceral vasomotor nerves then paralysed, but those also that supply the vessels of the whole body, head and upper extremities included; so that in cases of complete division, absolute paralysis of the whole vasomotor system must ensue; and if dilatation of the abdominal vessels were the main factor in the production of shock, it would follow *à fortiori* that the consequence of such an injury as this must be immediate death; while, as a matter of fact, instances are not unknown of recovery from the shock, which undeniably is severe, and of continuance of life with complete paralysis of motion and sensation in all parts below the seat of injury, the normal arterial tension being restored and maintained by means of the peripheral mechanism.

It will, I think, be admitted that these objections are fatal to the theory that dilatation of the abdominal vessels and enfeebled action of the heart are in themselves sufficient to account for the extreme degree of the fall in arterial tension met with in cases of shock; and that so simple a modification in the distribution of blood in the

body can induce such a condition. So long as the muscular fibres in the coats of the smaller vessels maintain their contractile energy and their connection with the nervous system, as Müller* has shown, the actual amount of circulating blood may be halved or doubled without producing any appreciable difference in the pressure: when these fail, and the elastic layers are left unsupported, the result that ensues is different in a most striking degree. Since this explanation of the fall of arterial pressure cannot be considered satisfactory, it is necessary to search for the cause further and wider among those conditions upon which depends during life the normal relation between the walls of the vessels and their contents, and to extend the inquiry over all the nervous structures which are concerned in maintaining this relation in heart, arteries, and capillaries alike; for it cannot be said that in this matter any one of these is of less importance than the others: they all participate, in nearly equal measure, and through precisely the same means. Each section of the vascular system in the body is controlled by the nervous apparatus through two mechanisms that may for convenience be regarded as distinct—one, independent, and acting for and by itself, so far as any part of the nervous system can be said to be independent; the other acting only through the cerebro-spinal system, and manifesting itself by the influence it exercises on the former. Of the heart this is acknowledged; while controlled by the cerebro-spinal centres through fibres which, on the faintest stimulus from any organ of sense, can convey an impulse that paralyses it at once, its normal and regular action is dependent for its immediate innervation on ganglia seated in its own walls; but with regard to the arteries this is not so generally admitted; apparently they are indebted to the central nervous system, not only for those impulses which can increase or diminish their state of tone, but for those also to which this owes its existence; but they must have local centres too, for if severed from all attachment with the central organ, the vessels, though paralysed at first, gradually recover their former tone, and then, though no longer capable of acting in harmony with the others that still maintain their central connection (except in an indi-

* Ludwig's *Arbeiten*, 1874.

rect way through the blood supply), they regain the power of keeping up their own state of contraction, and of varying it in compliance with local stimuli.

Of the third factor on which the maintenance of the arterial tension depends, the peripheral resistance, much less is known. Its very nature is obscure—how far it may be due to the mere physical force of friction, or how far it may depend upon the processes of vital interchange that take place between the tissues and the blood; but one thing is certain, that even supposing its continuance to depend on the unbroken activity of trophic nerves, these cannot yet be isolated in their action from those that govern the smaller arteries; so that for all practical considerations, these two may be associated together, and in the question as to the influence exerted by the nervous system in the maintenance of arterial tension, only the share taken by the heart on the one hand, and the smaller arteries on the other, need be discussed. And in spite of the great apparent difference in the methods by which these sections of the vascular mechanism are controlled, the principle is essentially the same: each owes the continuance of its existence to independent ganglionic centres, and the regulation and harmony of its work to stimuli that pass through the cerebrospinal system. The difference is simply this:—that in the case of the one the independently acting centres (whether really automatic or only reflex) remain peripheral, in the other they have become centralised and more plainly form the channel by which the influence of the cerebrospinal action is conducted; and it can be readily understood, from principles of physiological economy, why nerve ganglia which must have been widely scattered through the body, if they were to remain in the immediate neighbourhood of the vessels under their control, should have been gathered together into centres of progressively higher co-ordination, from ganglia of the sympathetic chain to spinal cord, and from thence to the great regulator centre of the medulla, in immediate proximity to the others that govern the functions of respiration and secretion; while the vessels still retain, as tissues and organs so often do, some traces of that primitive power of independent maintenance which, for the sake of the whole organism, must be subordinated to some central authority. And thus it may fairly be argued that

the two main structures which sustain and regulate arterial tension are not only under the direct control of the same series of nervous elements (only that in the case of one the ganglia are, for the sake of economy, gathered together and placed centrally), but that they are governed in the same way, and would be influenced by the same stimuli; and accordingly that the whole mechanism of the circulation may be regarded as one, only that some parts of it have become highly specialised; and these, owing to the minuteness and distance of their ramifications, have more need to be brought into union with a single central regulating organ than that which is endued with simpler and more purely mechanical functions. One impulse then could act at once and simultaneously on the whole circulation, and a reduction in the blood pressure could result, not from the paralysis of one part, such as the heart, but of the whole at once. And this is the change that takes place in shock. It is not the heart or the dilated abdominal vessels, or both of these together, but the more or less complete paralysis of the entire muscular portion of the circulatory apparatus, in heart and arteries alike; and with this possibly the cessation of those relations between tissues and blood that normally are carried on through the capillary wall. No change of less extent can account for so sudden and so extreme a loss of arterial tension: it is a lesser degree of that which normally takes place during the death of an animal; and shock itself seems but a lesser degree of death. The history of its development bears out this view of the unity of the circulation. Equally in the growth of the individual and in that of the race, its structure is perfectly uniform and simple at its first appearance; then, step by step with the increasing size and complexity of the other parts of the body, in accordance with the ordinary principles of the division of labour, its duties become divided and localised, till at length some portions attain so high a degree of specialisation that they are usually thought of and studied as if they were independent: in reality the whole mechanism still remains one, and in its connection with the nervous system, however diversified this may seem to be, there may be found the trace of that original union which binds the specialised parts into one consistent whole.

It yet remains to show how it is that the nervous system,

the great conception of which points rather to the conveyance of stimuli to action, can exert such a powerful and universal paralysing influence.

It has been suggested that, as in syncope, the immediate cause of the symptoms is to be found in the anæmia of the cerebral hemispheres, so a more general diminution in the amount of blood throughout all the nerve centres is in shock the source of this suspended action, either directly or by the fall in the arterial pressure, which Mayer has shown would result from such a condition; and that if this latter were the case the capillary circulation through the nerve centres would suffer equally with that of the rest of the body, and thus the already existing state of depression would be intensified and prolonged. The only experiments, and from them alone can proof be derived, which would tend to support this theory, are those already mentioned of Mayer,* on the influence of cerebro-spinal anæmia; and some of Brown Sequard,† on its production. The former consisted in inducing different degrees of bloodlessness of the nerve-centres for various lengths of time by deligating or compressing the main arteries; and then, after a sudden release, noticing the effect produced—a fall in the blood-pressure so extreme as to be called “paralytic,” and proved, with a fair amount of probability, to be due to paralysis of the vasomotor fibres running in the upper part of the cervical cord: the latter, even more complicated, were conducted with a view to show the contraction of the vessels in the pia mater of the cord resulting from such an injury to the abdominal viscera as passing a ligature round the hilus of a kidney, or tearing out one of the supra-renal bodies; but these experiments are of such difficulty, and have been repeated by subsequent observers with such slight success, that Vulpian considers it very doubtful if the conclusions drawn from them are justified. It seems very much more reasonable and more simple to refer phenomena of this kind to that power of inhibition with which, especially as manifested on the vasomotor system, every one is familiar; and indeed the difficulty is rather to determine whether this power in which all nerve structures have a share, and which probably is brought into play during

* Sitzung: d. k. Acad.: d. Wiss: in Wien. Band, 79. Heft. I.

† Archives Generales de Médecine, 1856. Tome VIII.

the co-ordination of every nerve impulse, instead of indirectly causing the symptoms of shock through its action on the vascular system, may not be the direct and immediate agent influencing the nerves that govern sensation and motion and volition, as much as those that control the walls of the blood vessels; whether the paralysis of sensation and motion and the impairment of reflex action, instead of being secondary effects produced through the intermediate agency of the circulation, may not be due to the direct influence of some molecular change in the nerve centres. It is highly probable that many of the so to speak accessory consequences of injuries, the immediate dependence of which on the actual damage is not apparent, are due to some cause closely analogous to this; and especially is this true of injuries to the nerve-centres, and of consequences, that make their appearance at once, and gradually disappear. A powerful stimulus applied to a sensory nerve can entirely obliterate a slighter one. After laying open the spinal canal, irritation of the posterior roots is for some considerable time followed by no result. After section of the cord, reflex phenomena are not witnessed till the inhibitory influence is wearing off; and if, when these have returned, and the animal has recovered, so far as is consistent with the continuance of paraplegia, a second section is carried through higher up, only those parts of the body are affected which are indebted for their innervation to the portion of the cord above the original section. Those below, severed from all nerve connection with the injured portion, manifest no diminution of reflex excitability, none of the symptoms of shock, only a contraction of their blood vessels consequent on a loss of pressure in the rest of the body.* The spinal cord and the peripheral nerves are not the only nerve structures which furnish examples. Violent emotions, fear or joy, can either increase the normal inhibitory power of centres that are in continuous activity, or can check the action of others that seem thoroughly independent, and this is equally true of the very highest manifestations of nerve power of which the brain is capable.

Further, as by such influences as excessive emotion, or

* Goltz. Pflüger's Archiv. 1875.

an electric shock, it is possible, without the production of any structural alteration, to interrupt the continuance of those molecular changes which constitute nerve force, so that they can never be resumed, it does not seem altogether unwarrantable to assume that there may be other influences, depending either upon the condition of the individual or of the surroundings, which can modify them in such a manner as to alter the normal effect of stimuli ; and in this way it may be possible to explain the different degrees of vital depression that may result from apparently the same injury at various times, and the difference in the duration and the gravity of the symptoms. Hæmorrhage and prolonged nerve exhaustion are beyond question influences which possess this power ; for it has been shown experimentally that a stimulus applied to an exhausted nerve centre is only followed by an increase in the depression ; and a similar reversal of the ordinary effect of a stimulus is known to occur when certain poisons, of which chloral is one, are circulating in the blood in sufficient quantity.

The most prominent phenomenon then in shock, the extreme diminution in arterial tension, is primarily due to the power of inhibition which is one of the inherent properties of the nerve centres ; and which, under some conditions, of which we have as yet only an idea, is capable of affecting simultaneously the ganglia that control the whole vascular system. It is a question how far the symptoms are due to the immediate influence of inhibition on other nerve centres ; and how far to the secondary effects produced through its influence on the blood pressure. There is one observation made by Weir Mitchell (*New York Med. Journal*, 1866) which would point to the former being at any rate sometimes true ; that in the variety of the cerebral phenomena presented by cases of shock, there is evidence of a change, less constant in its effects, than would be that of mere alteration in the amount of blood.

