THE ORIGIN AND NATURE

of the

EMOTIONS

Miscellaneous Papers

BY

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PREFACE

IN response to numerous requests I have brought together into this volume eight papers which may serve as a supplement to the volumes previously published[*] and as a preface to monographs now in preparation.

[*] Surgical Shock, 1899; Surgery of the Respiratory System, 1899; Problems Relating to Surgical Operations, 1901; Blood Pressure in Surgery, 1903; Hemorrhage and Transfusion, 1909; Anemia and Resuscitation, 1914; and Anoci-association, 1914 (with Dr. W. E. Lower).

In the first of these addresses, the Ether Day Address, delivered at the Massachusetts General Hospital in October, 1910, I first enunciated the Kinetic Theory of Shock, the key to which was found in laboratory researches and in a study of Darwin's "Expression of the Emotions in Man and in Animals," whereby the phylogenetic origin of the emotions was made manifest and the pathologic identity of surgical and emotional shock was established. Since 1910 my associates and I have continued our researches through— (a) Histologic studies of all the organs and tissues of the body; (b) Estimation of the H-ion concentration of the blood in the emotions of anger and fear and after the application of many other forms of stimuli; (c) Functional tests of the adrenals, and (d) Clinical observations.

It would seem that if the striking changes produced by fear and anger and by physical trauma in the master organ of the body— the brain—were due to WORK, then we should expect to find corresponding histologic changes in other organs of the body as well. We therefore examined every organ and tissue of the bodies of animals which had been subjected to intense fear and anger and to infection and to the action of foreign proteins, some animals being killed immediately; some several hours after the immediate effects of the stimuli had passed; some after seances of strong emotion had been repeated several times during a week or longer.

The examination of all the tissues and organs of these animals showed changes in three organs only, and with few exceptions in all three of these organs—the brain, the adrenals, and the liver. The extent of these changes is well shown by the photomicrographs which illustrate the paper on "The Kinetic System" which is included in this volume. This paper describes many experiments which show that the brain, the adrenal, and the liver play together constantly and that no one of these organs—as far at least as is indicated by the histologic studies—can act without the co-operation of the other two.

Another striking fact which has been experimentally established is that the deterioration of these three organs caused by emotion, by exertion, and by other causes is largely counteracted, if not exclusively, during sleep. If animals exhausted by the continued application of a stimulus are allowed complete rest for a certain number of hours, **without sleep*, the characteristic histologic appearance of exhaustion in the brain, adrenals, and liver is not altered notably, whereas in animals allowed to sleep for the same number of hours the histologic changes in these organs are lessened— in some cases obliterated even.

This significant phenomenon and its relation will be dealt with in a later monograph.

Many of the arguments and illustrations by which the primary premises were established are repeated—a few in all—many in more than one of these addresses. It will be observed, however, that the APPLICATION of these premises varies, and that their SIGNIFICANCE broadens progressively.

In the Ether Day Address the phylogenetic key supplied by Darwin was utilized to formulate the principle that the organism reacts as a unit to the stimuli of physical injury, of emotion, of infection, etc. To the study of these reactions (transformations of energy) the epoch-making work of Sherrington, "The Integrative Action of the Nervous System," gave an added key by which the dominating role of the brain was determined. Later the original work of Cannon on the adrenal glands gave facts, and an experimental method by which Darwin's phylogenetic theory of the emotions was further elaborated in other papers, especially in the one entitled "Phylogenetic Association in Relation to the Emotions," read before The American Philosophical Society in April, 1911. GEORGE W. CRILE. CLEVELAND, OHIO, *February, 1915*.

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 THE ORIGIN AND NATURE OF THE EMOTIONS

PHYLOGENETIC ASSOCIATION IN RELATION TO CERTAIN MEDICAL PROBLEMS[*]

[*] Address delivered at the Massachusetts General Hospital on the sixty-fourth anniversary of Ether Day, Oct. 15, 1910.

The discovery of the anesthetic properties of ether and its practical application to surgery must always stand as one of the great achievements of medicine. It is eminently fitting that the anniversary of that notable day, when the possibilities of ether were first made known to the world, should be celebrated within these walls, and whatever the topic of your Ether Day orator, he must fittingly pause first to pay tribute to that great event and to the master surgeons of the Massachusetts General Hospital. On this occasion, on behalf of the dumb animals as well as on behalf of suffering humanity, I express a deep sense of gratitude for the blessings of anesthesia.

Two years ago, an historic appreciation of the discovery of ether was presented here by Professor Welch, and last year an address on medical research was given by President Eliot. I, therefore, will not attempt a general address, but will invite your attention to an experimental and clinical study. In presenting the summaries of the large amount of data in these researches, I acknowledge with gratitude the great assistance rendered by my associates, Dr. D. H. Dolley, Dr. H. G. Sloan, Dr. J. B. Austin, and Dr. M. L. Menten.[*]

[*] From the H. K. Cushing Laboratory of Experimental Medicine, Western Reserve University, Cleveland.

The scope of this paper may be explained by a concrete example. When a barefoot boy steps on a sharp stone there is an immediate discharge of nervous energy in his effort to escape from the wounding stone. This is not a voluntary act. It is not due to his own personal experience— his ontogeny—but is due to the experience of his progenitors during the vast periods of time required for the evolution of the species to which he belongs, *i. e.*, his phylogeny. The wounding stone made an impression upon the nerve receptors in the foot similar to the innumerable injuries which gave origin to this nerve mechanism itself during the boy's vast phylogenetic or ancestral experience. The stone supplied the phylogenetic association, and the appropriate discharge of nervous energy automatically followed. If the sole of the foot be repeatedly bruised or crushed by a stone, shock may be produced; if the stone be only lightly applied, then the consequent sensation of tickling causes a discharge of nervous energy. In like manner there have been implanted in the body other mechanisms of ancestral or phylogenetic origin whose purpose is the discharge of nervous energy for the good of the individual. In this paper I shall discuss the origin and mode of action of some of these mechanisms and their relation to certain phases of anesthesia.

The word anesthesia—meaning WITHOUT FEELING—describes accurately the effect of ether in anesthetic dosage. Although no pain is felt in operations under inhalation anesthesia, the **nerve impulses excited by a surgical operation still reach the brain*. We know that not every portion of the brain is fully anesthetized, since surgical anesthesia does not kill. The question then is: What effect has trauma under surgical anesthesia upon the part of the brain THAT REMAINS AWAKE? If, in surgical anesthesia, the traumatic impulses cause an excitation of the wide-awake cells, are the remainder of the cells of the brain, despite anesthesia, affected in any way? If so, they are prevented by the anesthesia from expressing that influence in conscious perception or in muscular action. Whether the ANESTHETIZED cells are influenced or not must be determined by noting the physiologic functions of the body after anesthesia has worn off, and in animals by an examination of the brain-cells as well. It has long been known that the vasomotor, the cardiac, and the respiratory centers discharge energy in response to traumatic stimuli applied to various sensitive regions of the body during surgical anesthesia. If the trauma be sufficient, exhaustion of the entire brain will be observed after the effect of the anesthesia has worn off; that is to say, despite the complete paralysis of voluntary motion and the loss of consciousness due to ether, the traumatic impulses that are known to reach the AWAKE centers in the medulla also reach and influence every other part of the brain. Whether or not the consequent functional depression and the morphologic alterations seen in the brain-cells may be due to the low blood-pressure which follows excessive trauma is shown by the following experiments: The circulation of animals was first rendered STATIC by over-transfusion, and was controlled by a continuous blood-pressure record on a drum, the factor of anemia being thereby wholly excluded during the application of the trauma and during the removal of a specimen of brain tissue for histologic study. In each instance, morphologic changes in the cells of all parts of the brain were found, but it required much more trauma to produce brain-cell changes in animals whose blood-pressure was kept at the normal level than in the animals whose blood-pressure was allowed to take a downward course. In the cortex and in the cerebellum, the changes in the brain-cells were in every instance more marked than in the medulla.

There is also strong NEGATIVE evidence that traumatic impulses are not excluded by ether anesthesia from the part of the brain that is apparently asleep. This evidence is as follows: If the factor of fear be excluded, and if in addition the traumatic impulses be prevented from reaching the brain by cocain[*] blocking, then, despite the intensity or the duration of the trauma within the zone so blocked, there follows no exhaustion after the effect of the anesthetic disappears, and no morphologic changes are noted in the brain-cells.

[*] Since the presentation of this paper, novocain has been substituted for cocain in operations under anoci-association.

Still further negative evidence that inhalation anesthesia offers little or no protection to the brain-cells against trauma is derived from the following experiment: A dog whose spinal cord had been divided at the level of the first dorsal segment, and which had then been kept in good condition for two months, showed a recovery of the spinal reflexes, such as the scratch reflex, etc. Such an animal is known as a "spinal dog." Now, in this animal, the abdomen and hind extremities had no direct nerve connection with the brain. In this dog, continuous severe trauma of the abdominal viscera and of the hind extremities lasting for four <p 5-7> hours was accompanied by but slight change in either the circulation or in the respiration, and by no microscopic alteration of the brain-cells (Fig. 1). Judging from a large number of experiments on NORMAL dogs under ether, such an amount of trauma would have caused not only complete physiologic exhaustion of the brain, but also morphologic alterations of all of the brain-cells and the physical destruction of many (Fig. 2). We must, therefore, conclude that, although ether anesthesia produces unconsciousness, it APPARENTLY PROTECTS NONE OF THE BRAIN-CELLS against exhaustion from the trauma of surgical operations; ether is, so to speak, but a veneer. Under nitrous oxid anesthesia there is approximately only one-fourth as much exhaustion as is produced by equal trauma under ether (Fig. 3). We must conclude, therefore, either that nitrous oxid protects the brain-cells against trauma or that ether predisposes the brain-cells to exhaustion as a result of trauma. With these premises let us now inquire into the cause of this exhaustion of the brain-cells.

The Cause of the Exhaustion of the Brain-cells as a Result of Trauma of Various Parts of the Body under Inhalation Anesthesia

Numerous experiments on animals to determine the effect of ether anesthesia *per se*, *i. e*., ether anesthesia without trauma, showed that, although certain changes were produced, these included neither the physiologic exhaustion nor the alterations in the brain-cells which are characteristic of the effects of trauma. On turning to the study of trauma, we at once found in the behavior of individuals as a whole under deep and under light anesthesia the clue to the cause of the discharge of energy, of the consequent physiologic exhaustion, and of the morphologic changes in the brain-cells.

If, in the course of abdominal operations, rough manipulations of the parietal peritoneum be made, there will be frequently observed a marked increase in the respiratory rate and an increase in the expiratory force which may be marked by the production of an audible expiratory groan. Under light ether anesthesia, severe manipulations of the peritoneum often cause such vigorous contractions of the abdominal muscles that the operator is greatly hindered in his work.

Among the unconscious responses to trauma under ether anesthesia are purposeless moving, the withdrawal of the injured part, and, if the anesthesia be sufficiently light and the trauma sufficiently strong, there may be an effort toward escape from the injury. In injury under ether anesthesia every grade of response may be seen, from the slightest change in the respiration or in the blood-pressure to a vigorous defensive struggle. As to the purpose of these subconscious movements in response to injury, there can be no doubt— THEY ARE EFFORTS TO ESCAPE FROM THE INJURY.

Picture what would be the result of a formidable abdominal operation extending over a period of half an hour or more on an unanesthetized human patient, during which extensive adhesions had been broken up, or a large tumor dislodged from its bed! In such a case, would not the nervous system discharge its energy to the utmost in efforts to escape from the injury, and would not the patient suffer complete exhaustion? If the traumata under inhalation anesthesia are sufficiently strong and are repeated in sufficient numbers, the brain-cells are finally deprived of their dischargeable nervous energy and become exhausted just as exhaustion follows such strenuous and prolonged muscular exertion as is seen in endurance tests. Whether the energy of the brain be discharged by injury under anesthesia or by ordinary muscular exertion, identical morphologic changes are seen in the nerve-cells. In shock from injury (Fig. 2), in exhaustion from overwork (Hodge and Dolley) (Fig. 4), and in exhaustion from pure fear (Fig. 5), the resultant general functional weakness is similar— in each case a certain length of time is required to effect recovery, and in each there are morphologic changes in the brain-cells. It is quite clear that in each of these cases the altered function and form of the brain-cells are due to an **excessive discharge of nervous energy*. This brings us to the next question: What determines the discharge of energy as a result of trauma with or without inhalation anesthesia?

The Cause of the Discharge of Nervous Energy as a Result of Trauma under Inhalation Anesthesia and under Normal Conditions

I looked into this problem from many viewpoints and there seemed to be no solution until it occurred to me to seek the explanation in certain of the postulates which make up the doctrine of evolution. I realize fully the difficulty and the danger in attempting to reach the generalization which I shall make later and in the hypothesis I shall propose, for there is, of course, no direct final proof of the truth of even the doctrine of evolution. It is idle to consider any experimental research into the cause of phenomena that have developed by natural selection during millions of years. Nature herself has made the experiments on a world-wide scale and the data are before us for interpretation. Darwin could do no more than to collect all available facts and then to frame the hypothesis by which the facts were best harmonized. Sherrington, that masterly physiologist, in his volume entitled "The Integrative Action of the Nervous System," shows clearly how the central nervous system was built up in the process of evolution. Sherrington has made free use of Darwin's doctrine in explaining physiologic functions, just as anatomists have extensively utilized it in the explanation of the genesis of anatomic forms. I shall assume, therefore, that the discharge of nervous energy is accomplished by the application of the laws of inheritance and association, and I conclude that this hypothesis will explain many clinical phenomena. I shall now present such evidence in favor of this hypothesis as time and my limitations will admit, after which I shall point out certain clinical facts that may be explained by this hypothesis.

According to the doctrine of evolution, every function owes its origin to natural selection in the struggle for existence. In the lower and simpler forms of animal life, indeed, in our human progenitors as well, existence depended principally upon the success with which three great purposes were achieved: (1) Self-defense against or escape from enemies; (2) the acquisition of food; and (3) procreation; and these were virtually the only purposes for which nervous energy was discharged. In its last analysis, in a biologic sense, this statement holds true of man today. Disregarding for the present the expenditure of energy for procuring food and for procreation, let us consider the discharge of energy for self-preservation. The mechanisms for self-defense which we now possess were developed in the course of vast periods of time through innumerable intermediary stages from those possessed by the lowest forms of life. One would suppose, therefore, that we must now be in possession of mechanisms which still discharge energy on adequate stimulation, but which are not suited to our present needs. We shall point out some examples of such unnecessary mechanisms. As Sherrington has stated, our skin, in which are implanted many receptors for receiving specific stimuli which are transmitted to the brain, is interposed between ourselves and the environment in which we are immersed. When these stimuli reach the brain, there is a specific response, principally in the form of muscular action. Now, each receptor can be adequately stimulated only by the particular factor or factors in the environment which created the necessity for the existence of that receptor. Thus there have arisen receptors for touch, for temperature, for pain, etc. The receptors for pain have been designated *nociceptors* (nocuous or harmful) by Sherrington.

On the basis of natural selection, nociceptors could have developed in only those regions of the body which have been exposed to injury during long periods of time. On this ground the finger, because it is exposed, should have many nociceptors, while the brain, though the most important organ of the body, should have no nociceptors because, during a vast period of time, it has been protected by a skull. Realizing that this point is a crucial one, Dr. Sloan and I made a series of careful experiments. The cerebral hemispheres of dogs were exposed by removing the skull and dura under ether and local anesthesia. Then various portions of the hemispheres were slowly but completely destroyed by rubbing them with pieces of gauze. In some instances a hemisphere was destroyed by burning. In no case was there more than a slight response of the centers governing circulation and respiration, and no morphologic change was noted in an histologic study of the brain-cells of the uninjured hemisphere. The experiment was as completely negative as were the experiments on the "spinal dog." Clinically I have confirmed these experimental findings when I have explored the brains of conscious patients with a probe to determine the presence of brain tumors. Such explorations elicited neither pain nor any evidence of altered physiologic functions. The brain, therefore, contains no mechanism— no nociceptors—the direct stimulation of which can cause a discharge of nervous energy in a self-defensive action. That is to say, direct injury of the brain can cause no purposeful nerve-muscular action, while direct injury of the finger does cause purposeful nerve-muscular action. In like manner, the deeper portions of the spinal region have been sheltered from trauma and they, too, show but little power of causing a discharge of nervous energy on receiving trauma. The various tissues and organs of the body are differently endowed with injury receptors—the nociceptors of Sherrington. The abdomen and chest when traumatized stand first in their facility for causing the discharge of nervous energy, *i. e.*, THEY STAND FIRST IN SHOCK PRODUCTION. Then follow the extremities, the neck, and the back. It is an interesting fact also that different types of trauma elicit different responses as far as the consequent discharge of energy is concerned.

Because it is such a commonplace observation, one scarcely realizes the importance of the fact that clean-cut wounds inflicted by a razor-like knife cause the least reaction, while a tearing, crushing trauma causes the greatest response. It is a suggestive fact that the greatest shock is produced by any technic which imitates the methods of attack and of slaughter used by the carnivora. **In the course of evolution, injuries thus produced may well have been the predominating type of traumata to which our progenitors were* *subjected*. In one particular respect there is an analogy between the response to trauma of some parts of the body of the individuals of a species susceptible to shock and the response to trauma of the individuals in certain other great divisions of the animal kingdom. Natural selection has protected the crustaceans against their enemies by protective armor, *e. g.*, the turtle and the armadillo; to the birds, it has given sharp eyes and wings, as, for instance, the wild goose to another species—the skunk—it has given a noisome odor for its protection. The turtle, protected by its armor against trauma, is in a very similar position to that of the sheltered brain of man and, like the brain, the turtle does not respond to trauma by an especially active self-protective nerve-muscular response, but merely withdraws its head and legs within the armored protection. It is proverbially difficult to exhaust or to kill this animal by trauma. The brain and other phylogenetically sheltered parts likewise give no exhausting self-protective nerve-muscular response to trauma. The skunk is quite effectively protected from violence by its peculiar odor. This is indicated not only by the protective value of the odor itself, but also by the fact that the skunk has no efficient nerve-muscular mechanism for escape or defense; it can neither run fast nor can it climb a tree. Moreover, in encounters it shows no fear and backs rather than runs. The armadillo rolls itself into a ball for defense. On these premises we should conclude that the turtle, the armadillo, and the skunk have fewer nociceptors than has a dog or man, and that they would show less response to trauma. In two carefully conducted experiments on skunks and two on armadillos (an insufficient number) the energy discharged in response to severe and protracted trauma of the abdominal viscera was very much less than in similar experiments on dogs, opossums, pigs, sheep, and rabbits. It was indeed relatively difficult to exhaust the skunks and armadillos by trauma. These experiments are too few to be conclusive, but they are of some value and furnish an excellent lead. It seems more than a coincidence that proneness to fear, distribution of nociceptors, and susceptibility to shock go hand-in-hand in these comparative observations (Figs. 6, 7, and 8).

The discharge of energy caused by an adequate mechanical stimulation of the nociceptors is best explained in accordance with the law of phylogenetic association. That is, injuries awaken those reflex actions which by natural selection have been developed for the purpose of self-protection. Adequate stimulation of the nociceptors for pain is not the only means by which a discharge of nervous energy is caused. Nervous energy may be discharged also by adequate stimulation of the various ticklish regions of the body; the entire skin surface of the body contains delicate ticklish receptors. These receptors are closely related to the nociceptors for pain, and their adequate stimulation by an insect-like touch causes a discharge of energy,—a nerve-muscular reaction,— resembling that developed for the purpose of brushing off insects. This reflex is similar to the scratch reflex in the dog. The discharge of energy is almost wholly independent of the will and is a self-protective action in the same sense as is the response to pain stimuli. The ear in man and in animals is acutely ticklish, the adequate stimulus being any foreign body, especially a buzzing, insect-like contact. The discharge of nervous energy in horses and in cattle on adequate stimulation of the ticklish receptors of the ear is so extraordinary that in the course of evolution it must have been of great importance to the safety of the animal. A similar ticklish zone guards the nasal chambers, the discharge of energy here taking a form which effectively dislodges the foreign body. The larynx is exquisitely ticklish, and, in response to any adequate stimulus, energy is discharged in the production of a vigorous cough. The mouth and pharynx have active receptors which cause the rejection of noxious substances. The conjunctival reflex, though not classed as ticklish, is a most efficient self-protective reflex. I assume that there is no doubt as to the relation between the adequate stimuli and the nerve-muscular response of the various ticklish receptors of the surface of the skin, of the ear, the nose, the eye, and the larynx. These mechanisms were developed by natural selection as protective measures against the intrusion of insects and foreign bodies into regions of great importance. The discharge of energy in these instances is in accordance with the laws of inheritance and association. The other ticklish points which are capable of discharging vast amounts of energy are the lateral chest-wall, the abdomen, the loins, the neck, and the soles of the feet. The type of adequate stimuli of the soles of the feet, the distribution of the ticklish points upon them, and the associated response, leave no doubt that these ticklish points were long ago established as a means of protection from injury. Under present conditions they are of little value to man.

The adequate stimulus for the ticklish points of the ribs, the loins, the abdomen, and the neck is deep isolated pressure, probably the most adequate being pressure by a tooth-shaped body. The response to tickling in these regions is actively and obviously self-defensive. The horse discharges energy in the form of a kick; the dog wriggles and makes a counter-bite; the man makes efforts at defense and escape.

There is strong evidence that the deep ticklish points of the body were developed through vast periods of fighting with teeth and claws (Fig. 9). Even puppies at play bite each other in their ticklish points and thus give a recapitulation of their ancestral battles and of the real battles to come (Fig. 10). The mere fact that animals fight effectively in the dark and always according to the habit of their species supports the belief that the fighting of animals is not an intellectual but a reflex process. There are no rules which govern the conduct of a fight between animals. The events follow each other with such kaleidoscopic rapidity that the process is but a series of automatic stimulations and physiologic reactions. Whatever their significance, therefore, it is certain that man did not come either accidentally or without purpose into possession of the deep ticklish regions of his chest and abdomen. Should any one doubt the vast power that adequate stimulation of these regions possesses in causing the discharge of energy, let him be bound hand and foot and vigorously tickled for an hour. What would happen? He would be as completely exhausted as though he had experienced a major surgical operation or had run a Marathon race.

A close analogy to the reflex process in the fighting of animals is shown in the role played by the sexual receptors in conjugation. Adequate stimulation of either of these two distinct groups of receptors, the sexual and the noci, causes specific behavior— the one toward embrace, the other toward repulsion. Again, one of the most peremptory causes of the discharge of energy is that due to an attempt to obstruct forcibly the mouth and the nose so that asphyxia is threatened. Under such conditions neither friend nor foe is trusted, and a desperate struggle for air ensues. It will be readily granted that the reactions to prevent suffocation were established for the purpose of self-preservation, but the discharge of nerve-muscular energy to this particular end is no more specific and no more shows adaptive qualities than do the preceding examples. Even the proposal to bind one down hand and foot excites resentment, a feeling originally suggested by the need for self-preservation. No patient views with equanimity the application of shackles as a preparation for anesthesia.

We have now considered some of the causes of those discharges of nervous energy which result from various types of harmful physical contact, and have referred to the analogous, though antithetical, response to the stimulation of the sexual receptors. The response to the adequate stimuli of each of the several receptors is a discharge of nerve-muscular energy of a specific type; that is, there is one type of response for the ear, one for the larynx, one for the pharynx, another for the nose, another for the eye, another for the deep ticklish points of the chest and the abdomen, quite another for the delicate tickling of the skin, and still another type of response to sexual stimuli.

According to Sherrington, a given receptor has a low threshold for only one, its own specific stimulus, and a high threshold for all others; that is, the doors that guard the nerve-paths to the brain are opened only when the proper password is received. According to Sherrington's law, the individual as a whole responds to but one stimulus at a time, that is, only one stimulus occupies the nerve-paths which carry the impulses as a result of which acts are performed, *i. e.*, the final common path. As soon as a stronger stimulus reaches the brain it dispossesses whatever other stimulus is then occupying the final common path— the path of action. The various receptors have a definite order of precedence over each other (Sherrington). For example, the impulse from the delicate ticklish points of the skin, whose adequate stimulus is an insect-like contact, could not successfully compete for the final common path with the stimulus of a nociceptor. The stimulus of a fly on the nose would be at once superseded by the crushing of a finger. In quick succession do the various receptors (Sherrington) occupy the final common path, but each stimulus is for the time the sole possessor, hence the nervous system is integrated (connected) to act as a whole. Each individual at every moment of life has a limited amount of dischargeable nervous energy. This energy is at the disposal of any stimulus that obtains possession of the final common path, and results in the performance of an act. Each discharge of energy is subtracted from the sum total of stored energy and, whether the subtractions are made by the excitation of nociceptors by trauma, by tickling, by fighting, by fear, by flight, or by the excitation of sexual receptors, by any of these singly or in combination with others, the sum total of the expenditure of energy, if large enough, produces exhaustion. Apparently there is no distinction between that state of exhaustion which is due to the discharge of nervous energy in response to trauma and that due to other causes. The manner of the discharge of energy is specific for each type of stimulation. On this conception, traumatic shock takes its place as a natural phenomenon and is divested of its mask of mystery.