THE NERVOUS CORRELATE OF PLEASANTNESS AND UNPLEASANTNESS.

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CHAPTER II. AN HYPOTHESIS CONCERNING THE STRUCTURE AND FUNCTION OF THE NERVOUS SYSTEM.

If we wish to develop a plain and comprehensive view of the relation between consciousness and nervous activity, especially between pleasantness and unpleasantness and nervous activity, we must first of all develop a plain and comprehensive theory of nervous function. To what extent this latter theory can ultimately be accepted as right, is only of secondary importance in this connection, provided, of course, that the theory does not clearly contradict any facts known beyond doubt. It is easier to change details of a definite theory when necessary, than to make definite a theory which is vague at the start. Let us, then, base our considerations upon the hypothesis described in the following paragraphs.

1. *Structural Arrangement of the Nervous Elements: Centralization by Degrees.*

The nervous system of the simplest animals which possess nerve tissues may be regarded as a mere aggregation of reflex arches. By reflex arches we shall mean a system made up of three neurons (compare Fig. 1), a sensory and a motor neuron, and one connecting neuron. Actually, a reflex arch will hardly be found anywhere which does not contain a far greater number of connecting neurons. But here, in attempting to develop a schematic view, this fact may be neglected and a single connecting neuron be substituted for a chain of neurons made up of many links. By motor neuron we mean a neuron which has one of its ends in a motor point of the body, that is, in muscle fibers. By sensory neuron we mean a neuron which has one of its ends in a sensory point of the body, that is, in physiolog-

ical surroundings which particularly favor stimulation of this nerve end under special mechanical or physical or chemical conditions. Neurons which do not have one of their ends in either a sensory or a motor point of the body will be called connecting neurons.

It is self-evident that in all but the very lowest animals there must exist a connection between the different reflex arches.

FIG. 1.

Otherwise stimulation of a definite sensory point would always and inevitably result in the reaction of the same motor point of the body. But we know that such is not the case. Variations occur, so that the same stimulation which is originally followed by one reaction, is followed later by another. And further, stimulation of one sensory point may result in the reaction of a whole system of motor points; and stimulation of a whole system of sensory points may result in the reaction of a single motor point or at least only a small number of such points. We may use the term 'condensation of the motor process' or 'motor condensation' in order to refer to the latter effect or to the changes by which it is brought about. The term 'condensation of the sensory process' or 'sensory condensation' may refer to the former effect or to the functional changes in the nervous system by which it is brought about. Variation, sensory condensation, and motor condensation are then the three classes of phenomena which a comprehensive theory of nervous function must explain

before we can hope to draw conclusions as to the correlation between nervous and mental functions. In order to explain these phenomena, let us conceive the hypothesis that a number of reflex arches are united into a system as represented by Fig. 2. For simplicity's sake the figure represents only three reflex

FIG. 2.

arches, but we may conceive the number as high as we want to. We assume that the three sensory neurons which have their peripheral ends in S_1 , S_2 and S_3 , are connected by three connecting neurons having the common point S' . We also assume that the three motor neurons which have their peripheral ends in M_1 , M_2 and M_3 , are connected by three connecting neurons which possess the common point M' . Let us further assume that the points S' and M' are connected by the connecting neuron $S'M'$.

The whole system, then, is clearly like in kind to one of the simplest reflex arches from which we started. It is a reflex arch of a higher order. Among the connecting neurons within this system there are some which may be called sensory or

motor, in a relative sense, although they do not have one of their ends in a sensory or motor point of the body. However, those connecting neurons which pass down from S' are functionally nearer to sensory than to motor points of the body, those from M' nearer to motor points of the body.

We may now introduce and define a new term, very common in neurological literature, that of a 'nerve center.' Whatever the literal meaning of the word center, we shall mean by it simply an accumulation of functionally related connecting neurons. So we may say that the totality of the connecting neurons which have one of their ends at either S' or M' is a nerve center. In order to understand the significance of the terms 'lower' and 'higher' nerve centers, we may further develop the scheme of Fig. 2. Let us assume, as in Fig. 3, an aggregation of three systems, each like Fig. 2, representing any actual number of systems.

The points S' , S'_a and S'_b are in a relative sense sensory points. We assume them to be connected by three neurons having the common point S'' . The neurons, $S''S'$, $S''S'_a$, $S''S'_b$, belong to the class of connecting neurons, since they do not have one of their ends in a sensory point of the body. But in a relative sense they may be called sensory neurons, as being functionally nearer to sensory points than to motor points of the body. Similarly the neurons $M''M'$, $M''M'_a$, $M''M'_b$ may be called, in a relative sense, motor neurons, although they belong to the class of connecting neurons. The points S'' and M'' we assume to be connected by one neuron, as shown in the figure. We may now regard the totality of the neurons which have at least one of their ends either at S'' or at M'' as a nerve center, and we may name this center $S''M''$. This would be, relatively, a higher nerve center, and the nerve centers $S'M'$, or $S'_aM'_a$ would have to be called lower nerve centers. That is, the terms low and high as applied to a nerve center would have to be defined thus: A nerve center is to be called the higher the greater the number of steps (neurons) by which we could reach from it either a sensory or a motor point of the body.

Let us now imagine three systems (representing any actual

number of systems) like that of Fig. 3. Let us assume their, relatively speaking, sensory points S'' , S_a'' , S_b'' to be connected by three neurons having a common point, S''' (compare Fig. 4). Let us assume also their motor points M'' , M_a'' , M_b'' to be connected by three neurons having a common point M''' . Let us assume S''' and M''' to be connected by the connecting

FIG. 3.

neuron $S'''M'''$. The connecting neurons $S'''S''$, $S'''S_a''$, $S'''S_b''$ may then be called, in a relative sense, sensory neurons; and the connecting neurons $M'''M''$, $M'''M_a''$, $M'''M_b''$, in a relative sense, motor neurons. The totality of neurons which have one of their ends in either S''' or M''' , must then be called a nerve center higher than the nerve center $S''M''$, or $S_a''M_a''$, these being 'lower' centers in comparison with the center $S'''M'''$ and 'higher' centers in comparison with others, as we saw above. Let us now conceive this scheme of connections by higher and higher connecting neurons carried as far as the actual complexity of the human or an animal's nervous system would justify. Let us make the hypothesis that any nervous system is a system of connections of essentially the same kind as in the above scheme, and that the difference between the nervous systems of higher and lower animals consists in the existence of 'centers' (as above defined) of a higher order than

found in the lower animals, while the number of simple reflex arches may be identical in both classes.

We must at once raise the question whether this hypothesis agrees well enough with the fundamental neurological facts to deserve to be called probable. I shall mention two facts which seem to agree with the hypothesis.

FIG. 4.

If we examine the evolution of the nervous system, we notice that the nervous system shows a distinct tendency towards 'centralization.' Comparing the nervous system of a bird with that of a fish, we notice that it is not bulkier in each of the parts of the body, but that the increase in size is almost exclusively restricted to that part which in man has assumed such enormous size, the cerebral hemispheres. This manner of evolution is to be expected if the new additions to the nervous system serve no other purpose than that of making possible mutual connections of 'the highest centers' previously existing. The new additions are to be expected, then, at the very place where the last additions were made, where the last highest centers were added during the process of evolution, rather than anywhere else. In accordance with this we see the cerebral hemispheres expanding further and further, upwards, towards the sides, the back, and finally in a forward direction, entirely covering, in man, those masses of nervous tissue which were so

conspicuous when we opened the skull of a fish, demanding an enormous cranial cavity for their accommodation. And similar tendencies towards 'centralization' may be found, not only in the vertebrates, but even in invertebrates.

A second fact to be mentioned is the relation between the brain weight and the size of the whole animal organism. I expect to meet with assent if I regard the amounts of variation, of sensory condensation, and of motor condensation possible as measuring the degree of intelligence of an animal. Now, since the nervous tissues enclosed within the skull are not in their entirety higher centers, but to a considerable extent centers of the very lowest kind, that is, mere accumulations of reflex arches, the relative size of the brain cannot immediately be taken as an indication of relative intelligence, for the larger animal needs a greater number of reflex arches than the smaller animal. We must first answer the question, how the size of the brain depends on the size of the body when a species, through evolution, increases in size, but remains on the same level of intelligence. It is clear that the large majority of important stimulations occur on the body surface, where the body is most exposed to the influences of the environment. Stimulations within the internal organs are relatively insignificant. We must expect then, if a species increases in size, but remains on the same level of intelligence, that its brain will increase approximately in proportion, not to its body weight, but to its external surface. We may express this relation also thus: The weight of the brain must be approximately proportional, not to the third power of its linear measurement (m^3), but to the second power (m^2). If we wish to compare brain weight and body weight, because no other data are available than body weight, we may take the third root of the body weight and raise it to the second power ($m^2 = c \sqrt[3]{w^2}$). If we find that the ratio of the brain weight to this value is larger in one animal than in another we have the right to conclude that that animal excels in intelligence, since there is an excess of nervous tissue above that which is determined by the size of the body, an excess which, as higher nerve centers, can serve the three ends of variation, sensory condensation, and motor condensation. It is

remarkable that ideas like these have only in very recent years begun to find favor with neurologists, that the absurdity of a direct comparison of brain weights or even the ratios of brain weight to body weight, for estimating relative intelligence, has not been noted long ago.

The most interesting application of this principle is to be found in a comparison of the two sexes in man. The absolute weight of the male brain is considerably greater than that of the female brain, the ratio being 1.169 : 1 ; and fanatics have regarded this as a proof of the intellectual inferiority of woman. It was then pointed out that absolute measurement was valueless because woman is smaller in stature. The brain weight relative to body weight (br/w) is somewhat less in man than in woman, the ratio being .967 : 1 ; and although the difference is not great, fanatics have again regarded this as a proof, but, this time, of the intellectual superiority of woman. The brain weight relative to body surface ($br/\sqrt[3]{w^2}$) is slightly greater in man than in woman, the ratio being 1.029 : 1 ; and if we take into account that the increase of surface, while being the most important factor, is not the only one, that increase in bulk of the body, although a factor of minor importance, cannot be altogether neglected, our hypothesis concerning the architecture of the brain leads with great force to the conclusion that comparison of the weight of the brain teaches that there is no difference between the intelligence of man and woman. And this seems to be the outcome also of all direct investigations of the relative intelligence of the two sexes.

2. *Function of the Nervous System and its Consequences:* *Variation of Response, Sensory Condensation, Motor* *Condensation, Inhibition.*

Let us now return to our hypothesis of the structure of the nervous system. We assumed that the nervous system consists of reflex arches which are united into groups by higher connecting neurons, that these groups are again united into groups by still higher connecting neurons, and so on, in the manner indicated in our diagrams. We now have to make another hypothesis as to the function of this system, in order to explain the

original relative independence of the reflex arches and at the same time the possibility of variation of response, of sensory condensation, and of motor condensation developing during the individual's life. Let us note, however, that this functional hypothesis is by no means independent of the structural hypothesis, that it would not be applicable to every kind of conception of the structural organization of the nervous system.

It is well to formulate any hypothesis of this kind as far as possible in purely mechanical terms. The present writer does not share the views of those who believe that science must reduce the whole world to matter and motion. Nevertheless it is often preferable to state an hypothesis in mechanical rather than in other terms, in order to make it clear and to understand more readily its consequences.

1. Let us assume, then, that any point where two or more neurons are connected, functions like a valve which permits fluid to pass through only in one, not in the opposite direction, and that this valve opens only in the direction towards motor points of the body. For example, in Fig. 2, a current coming from S_1 and over α_1 reaching S' cannot pass through either of the other connecting neurons from S' down to y_1 or z_1 , but can pass on only in the direction of M' ; and a current coming from S_1 and over α_1 directly reaching α_2 cannot pass up to M' , but can proceed only in the direction of M_1 . A current which has reached M' , can proceed thence over α_2 to M_1 , or over y_2 to M_2 , or over z_2 to M_3 . The same principle applied to Fig. 3 would mean, for example, that a current which has reached S'' over S' can proceed only to M'' , not to S'_a or to S'_b ; and a current which has reached M' over either S' or M'' , can proceed only in the direction of either M_1 or M_2 or M_3 . No current can normally proceed in the direction $M'S'$, or $M'_a S'_a$, or $M''S'$, or $M'M''$.

2. Let us assume that any neuron system has functional properties analogous to those of a pipe system filled with a fluid, one end of the pipe system being usually closed (the sensory point), the other end being under the influence of negative pressure, or suction, tending to produce a current in the direction of this end, the motor point.

3. Let us assume that ordinarily no movement can take place in the pipe system because the sensory end is closed; that the application of a weaker or stronger stimulus means the same as the opening to a lesser or greater extent of the closed end of such a pipe system, thus permitting fluid to escape through the motor point. We assume that the fluid thus lost from the system is replaced in some way or other during the time when there is no stimulation, that is, no opening at the sensory point.

4. Let us assume that the resistance suffered by the fluid in moving through the pipe system depends in the ordinary manner on the length and the width of the pipe. The resistance depending on the length of the pipe line may be measured by counting in our diagrams the number of straight lines (neurons) of which a path from a sensory to a motor point of the body is composed, imagining that each line has the same actual length, whatever its length in the drawing. This does not preclude, of course, innate differences of resistance depending on other conditions.

5. Let us assume that a current has a tendency to widen the pipe in which it is occurring in proportion to its intensity and duration; and that any pipe, while no current is passing through it, has a tendency to grow narrower, gradually and very slowly. Let us further assume that both these properties of the pipe are present in the highest degree in the highest connecting neurons, in lower degrees in lower connecting neurons, and entirely absent in the sensory and motor neurons.

In five divisions we have thus stated a functional theory of the nervous system in mechanical terms. At the present time, when so little is definitely known about the processes going on in the nervous system and yet the need of such knowledge is so strongly felt, it seems to the present writer a decided advantage to be able to think of nervous function in purely mechanical terms, because of the clearness of such terms. But however clear, this hypothesis would be of no value unless its consequences agree with the fundamental facts of mental life. Let us now test the hypothesis in this respect.

Imagine a new-born animal with a nervous system like that

represented in Fig. 3. Let a stimulus be applied to S_2 . At every one of the nine motor points a reaction is possible. At M_2 because of the reflex arch $S_2y_1y_2M_2$. At M_1 because of the connection $S_2y_1S'M'x_2M_1$. At the motor points M_4 , M_5 , M_6 because of the connection $S_2y_1S'S''M''M'_a$. But the reaction at the motor points of the second and third groups must be very weak because the current has to go on in seven neurons. At M_1 and M_3 the reaction is not quite so weak because the current has to go on in only five neurons, so that there is less resistance. (The width of the pipe is assumed to be the same everywhere, although this might be otherwise.) At the point M_2 alone a strong reaction is to be expected, since M_2 can be reached from S_2 over three neurons, by way of y_1 and y_2 . It is clear that only at M_2 can a noticeable reaction occur; little or no reaction is possible at the eight other motor points. The function thus far studied illustrates therefore the phenomenon of reflex or instinctive activity, making allowance, of course, for the fact that this is a mere analogy, for no reflex, however simple, may be the result of quite as simple a nervous function.

If this function, the nervous correlate of instinctive activity, occurs frequently and at intervals not too long, according to our hypothesis the path y_1y_2 becomes somewhat widened—much more so than any of the other paths in which only weak currents have been active. The consequence is that the resistance of this path is slowly, but steadily reduced, that less and less current is possible along other paths, whose resistance is relatively high. In psychological terms, instinct becomes habit. Habit, however, means in this particular case no more than that when S_2 is stimulated the reaction at M_2 occurs even more exclusively, than originally. On the other hand it follows from our hypothesis that an instinct which is never used, through the gradual increase of resistance along the path, may become practically extinct. This might be called a negative habit.

Let us see, now, whether we can derive from our hypothesis the more important form of habit which consists in a variation of the original instinct. It is clear that such variation can come about only by simultaneous stimulation of at least two reflex arches. Suppose S_1 is stimulated simultaneously with S_2 , but

much more strongly than S_2 . According to our hypothesis the current over y_1y_2 must be much weaker than the one over x_1x_2 . To understand the conditions more clearly, we may separate the two reflex arches under discussion as in Fig. 5. Less current

FIG. 5.

is going over the longer paths of higher connecting neurons by way of $S'M'$, but here again there is unequal flux; the current in y_1S' must be much weaker than the one in x_1S' . These differences in flux are indicated in the figure by the relative thickness of the lines. Here we remember the dynamic principle that hydraulic pressure is less than hydrostatic pressure, of which the jet pump used for drainage or for exhausting air is a familiar illustration. The pressure diminution depends on the velocity of the fluid. It increases much more rapidly than the velocity of the fluid, being proportional to the square of the velocity. The consequence is that the fluid moving over x_1S' with a velocity greater than that of the fluid in y_1S' attracts the latter fluid. That is, more fluid takes the path over y_1S' and less the path over y_1y_2 than in case the point S_2 is alone stimulated. As we have made the assumption that the resistance of higher neurons (*e. g.*, y_1S' is more easily reduced by currents than that of lower neurons (*e. g.*, y_1y_2) the resistance of y_1S' might soon become less than that of y_1y_2 , although the velocity in y_1S' did not, perhaps, at any time become actually less than that in y_1y_2 . At the same time the resistance in $S'M'$ and $M'x_2$ must decrease because of the great flux from S_1 . Because of the great flux over $x_1x_2M_1$ the hydraulic pressure at the point x_2 must be low and act upon the fluid in $S'M'$ as suction, so that

but little of this fluid can move over $M'y_2$. The consequence of all this is that an ever-increasing amount of the fluid moving through S_2y_1 moves on in the direction of M_1 by way of the path indicated by the zigzag lines y_1S' and $M'\alpha_2$, an ever decreasing amount in the direction of M_2 . The outcome of this is that when some time later the sensory point S_2 is stimulated separately, the current passes on over $y_1S'M'\alpha_2$ to M' , finding here less resistance than over $y_1y_2M_2$. That is, the original reflex arch has been put out of function, an instinct has been modified into a habit with a different kind of reaction. Of course, one condition must be fulfilled while the habit is being formed: S_2 must not too frequently be stimulated alone, for this would tend to decrease the resistance of the neuron y_1y_2 and would thus interfere with the development of the variation.

How can sensory condensation be explained on the basis of our hypothesis? The explanation by the aid of Fig. 5 is not difficult. Suppose that the combination just discussed occurs frequently, and that the stimulation symmetrically opposite occurs with about equal frequency, S_2 being stimulated strongly and S_1 at the same time weakly, but that neither S_1 nor S_2 are much stimulated separately. The consequence is that the resistance of $\alpha_1\alpha_2$ as well as of y_1y_2 increases gradually, whereas the resistance of the path $\alpha_1S'M'y_2$ as well as of the path $y_1S'M'\alpha_2$ decreases. The ultimate outcome of this development must be this: When finally the sensory point S_1 is stimulated alone, the current proceeds, not over $\alpha_1\alpha_2$, but over α_1S' to M' , divides here equally, and equal reactions occur at the motor points M_1 and M_2 simultaneously. And also, when the sensory point S_2 is now stimulated alone, the current proceeds, not over y_1y_2 , but over y_1S' to M' , divides here equally, and equal reactions occur at the motor points M_1 and M_2 simultaneously. That is, while two stimuli at S_1 and S_2 were originally required to bring about simultaneous reaction at M_1 and M_2 , a single stimulus is now sufficient for the same result. We have developed the kind of habit which we called sensory condensation.

Our next task is to explain from our hypothesis the development of habits of the kind which we have called motor condensation. This explanation is a simple matter if we recall our

explanation of variation of response. We saw that when S_2 is rarely stimulated alone, but frequently together with S_1 in such a manner that the stimulation of S_1 is stronger than that of S_2 , the channel y_1y_2 tends to close and the current, when S_2 is finally stimulated alone, takes the path $S_2y_1S'M'x_2M_2$. It is plain that when this stage of development has been reached, simultaneous stimulation of S_1 and S_2 , whatever the relative intensities of the stimuli at S_1 and S_2 , can result in nothing more than in a reaction at the single motor point M_1 . Thus we explained in mechanical terms, on the basis of a structural and functional hypothesis the three fundamental facts of genetic psychology, variation of response, sensory condensation, and motor condensation. If we look at Figs. 3 and 4, we see at a glance that the application of this explanation to higher and higher 'nerve centers' is in no respect different from the explanation when applied to the nerve center in Fig. 2. That the same rules are applicable throughout must be regarded as a particular advantage of the structural and functional hypothesis upon which the explanation is based.

There is one further conception of fundamental importance in psychology, that of inhibition. I do not, of course, use the term inhibition here in the sense in which it is often used by physiologists, referring to the fact that a certain organ may be made to function rapidly by one kind of nervous influence, to function slowly—or perhaps, in reversed manner—by another kind. I have in mind the fact that a motor reaction expected in consequence of appropriate sensory processes or imagery, is often suppressed by sensory processes or imagery which—without being strictly opposed to that motor reaction—would not in themselves lead to it. For example, a student walking home, suddenly stops on the sidewalk, forgets that dinner is waiting for him, in consequence of thinking of the problem in geometry given him by his teacher. How is this kind of inhibition, which in its most conspicuous appearances is attributed particularly to the very highest nerve centers, to be explained from our hypothesis?

Let us remember our explanation of the variation of response. When S_2 in Fig. 5 is stimulated, we expect a reaction at M_2 .

But this reaction does not take place if a much stronger stimulus is simultaneously applied to S_1 , bringing about a reaction at M_1 . The expected reaction at M_2 is inhibited. It then becomes at once clear why inhibition depends so largely on the function of the very highest nerve centers. In our above case there could be no inhibition if the two systems of reflex arches did not have the higher connecting neuron $S'M'$ in common. There could be but little of the phenomenon of inhibition in our mental life if we did not possess — in the sense of the diagram of Fig. 4 — very high 'nerve centers,' belonging anatomically to different reflex arches which, as simple reflex arches, are perhaps entirely separate from each other, serving to produce movements which are mutually independent.

CHAPTER III. A THEORY OF THE NERVOUS CORRELATE OF PLEASANTNESS AND UNPLEASANTNESS.

We are now prepared to raise and answer the question as to the nervous correlate of consciousness. Whoever accepts our previous discussions based on our structural and functional hypothesis can hardly hesitate to answer, that consciousness accompanies processes in the 'higher' connecting neurons, the higher 'nerve centers,' whereas processes restricted to the lower centers may go on without any consciousness. A definite line in this respect cannot be drawn. It is impossible to state just how high the centers involved, how indirect the neuron connections leading from sensory to motor points of the body have to be in order to be accompanied by consciousness. Nevertheless there will scarcely be any objection to the general statement of this dependence. It is also natural to assume that the consciousness must be the more elaborate, consisting of sensory impressions and whole trains of associated imagery, the more indirect the paths taken by the current, the more delayed accordingly the motor response.

What then is the nervous correlate of pleasantness and unpleasantness? If we held, as one of the psychologists mentioned, that unpleasantness was merely a weak sensation of pain and pleasantness merely a weak sexual sensation, then no further answer would be necessary, the answer would have

been given already. But we hold that pleasantness and unpleasantness are states of consciousness differing in kind from sensations, perceptions, images, ideas. One principle must be adhered to. We must not multiply conditions beyond need. We must apply the same views without change as long as comparison with the facts of experience permits. We have assumed that sensation and imagery depend on activity of the higher connecting neurons of the nervous system. Let us therefore assume that pleasantness and unpleasantness too, depend on activity of the higher connecting neurons. But if pleasantness and unpleasantness are different in kind from sensation and imagery, then the kind of 'functional' (in a mathematical sense) relation between nervous activity and pleasantness and unpleasantness is likely to be found to be a different one.

Asking, then, the question as to what constitutes the nervous correlate of pleasantness, we give this answer. The nervous correlate of pleasantness and unpleasantness must be *some form of activity in the higher nerve centers*, since it is generally admitted that only activities in the higher nerve centers are accompanied by consciousness, and pleasantness and unpleasantness are kinds of consciousness. But while the correlate of sensation is the nervous current itself, the *correlate of pleasantness and unpleasantness is the increase or decrease of the intensity of a previously constant current if the increase or decrease is caused by a force acting at a point other than the point of sensory stimulation.*

Some psychologists will doubtless be quick to raise the objection that the correlate of a mental state must be a 'physical state,' a nervous process going on in a mysterious 'feeling center,' that it is *inconceivable* that the nervous correlate of pleasantness or unpleasantness could be a mere increase or decrease in the rate of flow. However, things are often inconceivable for the sole reason that they have never been conceived. That heat, light, magnetism, electricity, are anything but substances capable of flowing from one place to another has been inconceivable to some, that they are anything but forms of vibratory motion of a hypothetical ether has been inconceivable to others.

And still there are those who conceive of them as mere periodical changes in the distribution of energy. If preconceived notions were less strong in psychology than anywhere else in human activity, the psychology of feeling would long ago have passed out of the state of confusion in which we find it at present. Nothing is inconceivable but that which implies a logical contradiction. The theory above advanced does not contain such a contradiction. Its scientific value, of course, is not proved thereby, but depends on its capacity for bringing the varied experiences referred to by feeling or by pleasantness-unpleasantness under a clearer and more comprehensive formula than other theories are capable of. That there is an increasing tendency among psychologists toward some such theory as the above appears from some of the views reported in our historical introduction and similar views expressed in some recent text-books on general psychology. However, I do not know of any attempt at giving this theory any formulation which can compare in definiteness with the one presented above.

The most difficult part of our task is still before us, that of showing that the varied experiences of pleasantness and unpleasantness become easily intelligible as special cases of the general fact stated. The difficulty of this task, however, is not—as is often the case with theories—the result of a lack of definiteness; it is the consequence of the enormous complexity of the conditions under which pleasantness and unpleasantness come to be felt in ordinary life. We must therefore restrict ourselves at present to applying our theory to a number of typical instances.

1. *Pleasantness-Unpleasantness Does not Occur Apart from Perception.*

Writers on psychological theory usually emphasize the fact that pleasantness and unpleasantness seem to lack independence, that they cannot occur alone but only as an accompaniment of sensory or ideational states. Some have felt constrained under these circumstances to assume that pleasantness and unpleasantness are attributes of all sensations, that every sensation has a feeling-tone, positive, negative, or indifferent. This doctrine

of the feeling tone of sensation must be rejected because it does not fit such cases as that mentioned by Miss Calkins where a person mistakes an ice-cream fork for an oyster fork. But it must be admitted that pleasantness and unpleasantness never occur alone, separate from sensory or ideational mental states. Now this is just what is to be concluded from our theory. There can be no increase or decrease of a nervous process without the nervous process existing itself. Therefore there can be no pleasantness or unpleasantness without sensory or ideational content. On the other hand, a nervous process can exist without increasing or decreasing. It is true that a nervous process cannot come into existence without increasing or go out of existence without decreasing. But this increase or decrease is the consequence of conditions existing at the point of stimulation, and is therefore, according to our theory, not the correlate of any pleasantness or unpleasantness.

2. *Pleasantness-Unpleasantness Is Not Localized.*

Excepting a few psychologists there is a general agreement that pleasantness and unpleasantness cannot be localized, whereas all sensations can be localized, although not always very exactly. Nothing else could be the case according to our theory. We can localize the sensory point from which a nervous process takes its origin, for instance, by imagining the visual appearance of that sensory point amidst its surroundings. But it is obviously impossible to have, visually or by other sensations, any experience of the point within the central nervous system where the decrease or increase of the nervous process originates. Sometimes, however, we know or think we know that the decrease or increase has its indirect cause in a certain sensory stimulation, as, for example, when we are studying and hear our neighbor's piano. Some psychologists may describe this experience by saying that they localize unpleasantness in the ear, but the majority will probably insist that the unpleasantness of this experience is not localized anywhere, that the sound only is localized in the ear.

3. *Certain Sensations Are Usually Unpleasant.*

Certain sensations, for example, pain, bitterness, acidity, are nearly always unpleasant. But it would be misleading to state that this is the feeling-tone of these sensations — a doctrine which we have already rejected. Many articles of food which are but slightly sour or bitter, are pleasant to eat. And psychologists are coming more and more to recognize the fact that even the sensation of pain, in its lower degrees, is not invariably unpleasant. The relation of these facts to our theory is not difficult to see. One may distinguish two ways in which the sensation of pain may be brought about, by a movement on the part of the subject, as when I lift my hand and thus come in contact with a sharp instrument, and by an influence of another kind while my body is at rest, as when I am unawares bitten by a dog. However, there is no fundamental difference between these two cases, for rest too, in ordinary life, means a definite kind of muscular innervation. Now, if my nervous organization, by both instinct and habit, were such that the nervous processes going on at the time when my hand was bitten could remain the same after this event as before, the probability is that the dog would bite me again and would thus diminish my chances for life. It is entirely in accord with what we must expect from the necessities of life when we find that the sensory processes resulting from the application of the dog's teeth bring about cessation of the muscular innervation existing at that moment and substitution of another kind of muscular activity. We see at once that for this purpose it is necessary and unavoidable that I be so organized nervously that the two processes, the one which results in what we called rest and the new one which originates from the point where my pain nerves were stimulated, and which results in withdrawal of the hand and in other movements of defense, meet somewhere in the nervous system. According to our structural hypothesis any two nervous processes can meet somewhere. As soon as the second process meets the first, it will through its own greater intensity detract from the first process and thus bring about the cessation of the muscular activity which had existed up to the time of biting. If the meeting of the two nervous processes occurs in 'nerve centers' which

are not very high there is no accompanying consciousness. The movement of defense would be called instinctive or automatic. Something like what we have described might occur during sleep without the subject's awaking. But if the meeting occurs in a very high nerve center, there must be the consciousness of the sensation of pain and other ideas associated. The defensive movement in this case would be called voluntary. And now, there must also be, according to our theory, a conscious state of unpleasantness whose intensity depends on the *rate* at which the first nervous process is *deflected* from its original course into that of the second process — which is identical with the rate at which the original flux is *decreased*. The flux of the second process is thus increased, but this, according to the theory, does not result in pleasantness because the second process is only establishing itself, has not previously been constant.

It is not strange, then, that the sensation of pain is nearly always accompanied by unpleasantness. But there are some, though rare, cases where the sensation of pain is not accompanied by unpleasantness. From our theory we can understand these cases as well as the more common case just discussed. Those, for example, who are chronically sick and suffer constant pain, would only injure themselves by reacting upon pain as a normal person reacts upon a dog bite. They learn to continue the muscular activity in which they are engaged even when the sensation of pain suddenly makes itself felt. That is, the new nervous process is no longer able to meet the first process, to detract from the first process, but takes its separate path leading to some kind of muscular activity irrelevant to the subject. According to our theory there can then be no unpleasantness. Psychologists have often thought to give a complete description of such a case by simply stating that the invalid pays no attention to the sensation of pain. While it is doubtless true that very often he does not pay any attention to the pain, that very often the second process does not reach any higher centers, in the opinion of the present writer this is not the whole truth, but must be supplemented by showing that even when attention is paid there need not be any unpleasantness; and this we have shown above.

Imagine a scientist, perhaps a psychologist, studying experimentally the sensation of pain. He cuts out a piece of his skin and records carefully how the sensation of pain develops. It is not astonishing if we are told that, although he felt the sensation of pain, he felt no unpleasantness. If the nervous process starting from his pain nerves had interfered with, detracted from those processes going on at the moment, his experiment would have been a failure because it would have been cut short. If he is so interested in the experiment that he succeeds in bringing it to the proper end, then there can have been no unpleasantness, for there has been no deflection of his nervous processes. There might have been even pleasantness, for the sensation of pain, being expected, may induce the experimenter to cut further. The nervous process starting from the sensory nerves of pain in this case did not take any course of its own, but joined the nervous processes going on at the time when it started, increasing their intensity.

Insects have bitten us, and the itching thus caused produces scratching movements. Pain is the result of the scratching; but this pain is by no means unpleasant, rather pleasant. Why? The pain does not stop us scratching. On the contrary we scratch the more for it. The nervous process starting from the pain nerves joins the process going on when the pain was first produced. However, if the pain becomes too strong, then the sensory process of pain intercepts the previous process, a typical pain reaction follows, scratching ceases, and unpleasantness is felt.

If a sour or bitter substance is put in an infant's mouth, the instinctive response is that of spitting. The new nervous process intercepts those going on at the time, and unpleasantness is felt. While the tastes of sour and bitter are invariably unpleasant to children, they are often found to be pleasant in older people unless they occur in too strong a degree. Some people like bitter beer and sour pickles. How does this come about? The answer is not difficult. If for one reason or other, that is, under the influence of strong nervous processes which overpower the instinct, sour or bitter food is frequently taken, the resistance of the path representing the original instinct is increased, accord-

ing to our theory, and a new nerve path of small resistance leading to the movement of sucking and swallowing is formed. Whenever now a movement occurs which brings a slightly bitter substance into the mouth, for instance the movement of sucking beer from a mug, the nervous process resulting from the bitter stimulation is of essentially the same kind as the one which has been going on and therefore simply joins it, increasing its intensity. According to our theory pleasantness must then be experienced.

But why should the sensation of bitter be unpleasant to the same subject when recurring in a much higher degree, caused, say, by a dose of quinine? Now, we did not say that the original (instinctive) nerve path has been entirely obliterated. The stronger the stimulus the greater the diffusion of the nervous process. This diffusion is to be expected particularly in the direction over the original path. This path was by inheritance, and is still, connected with a large number of the most ordinary motor paths, in order to insure to the animal the protection so necessary against getting harmful substances into the mouth. It is highly probable, then, that this strong process passing over the instinctive path will be joined by other accidental nervous processes, that thus it will become still stronger until its intensity becomes greater than that of the other branch passing over the habit path. Immediately, according to our theory, the habit process is intercepted and the original instinct has for the moment full sway. Unpleasantness is the logical consequence.

Although there is a natural aversion against tobacco, alcohol, and other drugs, their taste and smell, etc., may be made pleasant by simply using these substances persistently in spite of the original instinct, till the instinct is sufficiently weakened, that is, the resistance of the reflex arch sufficiently increased. The establishment of the habit must be quickened, of course, by changes in the chemical constitution of the nervous system and the sense organs, which take place in consequence of the organism's adapting itself as well as possible to the continued prevalence of unnatural conditions.

4. *Certain Sensations Are Usually Pleasant.*

Certain sensations are almost invariably pleasant. Sweet and sexual sensation are good examples, so much so that some psychologists, as we saw in our introduction, have been misled into regarding pleasantness as a weak sexual sensation. It is plain that, if animals were so organized nervously that the nervous process starting from stimulation of the sexual sensory nerves were likely to intercept those nervous processes leading to the muscular innervation existing at the moment of stimulation, fertilization of the ovum and thus propagation of the race would be a highly improbable occurrence. But the nervous system of all animals is by inheritance of such a structure that the higher connections of the reflex arches and the distribution of resistances cause the nervous process starting from stimulation of the sexual sense to join those processes existing at the moment of stimulation, to increase the intensity of the muscular innervation of this moment. The result is, according to our theory, pleasantness.

Nevertheless there are cases where the sexual sensation is indifferent or even unpleasant, just as there are cases where the sensation of pain is pleasant. Both the possibility and the comparative rarity of the sexual sensation's being unpleasant are easily comprehended from our theory. In a similar way the theory can be applied to the familiar experiences of pleasantness or unpleasantness of the sensation of sweet.

5. *Sensory and Intellectual Pleasantness and Unpleasantness.*

The chief objection to the doctrine of a feeling-tone of sensation is this, that pleasantness and unpleasantness accompanying ideational states are in a grown person's life much more numerous and also, on the whole, much more intensive than pleasantness and unpleasantness accompanying sense impressions. It must be regarded as one of the points of superiority of our theory that it helps us to comprehend this fact without forcing us to distinguish sensory and intellectual pleasures as two different classes of mental states. According to our theory pleasantness can exist only when one nervous process is increased by a second and weaker process which is forced to join

it partially or wholly; unpleasantness can exist only when one nervous process is decreased by being partially or wholly intercepted by a second and stronger process. Such influences of a second nervous process on the intensity of an existing nervous process are possible only if the two processes meet somewhere in higher connecting neurons. It is at once clear that, as a rule, processes passing from sensory to motor points of the body over very indirect paths, by way of the highest connecting neurons, the 'highest centers,' are more likely to meet and interfere with each other than those which reach motor points of the body over very direct paths. The latter, however, are the nervous correlate of simple sensations and perceptions, the former the correlate of the more complex conscious processes made up of percepts and ideas, possibly long trains of thought. We comprehend thus why, on the whole, the highest intellectual activities give us the most intensive experiences of pleasantness and unpleasantness, whereas pleasantness and unpleasantness accompanying mere sensations are rather insignificant in the mental life of a person of culture.

6. *Positive and Negative Quantities.*

Pleasantness and unpleasantness have been regarded by many writers as positive and negative quantities the balance of which alone could have actual existence in conscious life. The present writer, from the introspective evidence of his own life, agrees with those psychologists (*e. g.*, Lipps) who hold that pleasantness and unpleasantness can exist at the same time. The belief that they exclude each other seems to have originated from the observation that when there is much pleasantness, there is, as a rule, no unpleasantness at all, and the reverse. Our theory explains, not only the fact just mentioned, but also the coexistence of pleasantness and unpleasantness in less frequent cases. We rarely do two things at the same time. This is a fact which we recognize as such without having to comprehend its biological sources. Doing one thing, however, does not mean that there is, in the strictest sense, only one nervous process passing through our organism from one sensory point to one motor point. Thousands of sensory neurons are stimulated and

thousands of muscle fibers receive innervations from their motor neurons simultaneously. But all these nervous processes must be thought of as running parallel, without any mutual interference. Recalling our Fig. 2, and supposing the reflex arches S_1M_1 , S_2M_2 , S_3M_3 to represent such parallel nervous processes, it is easily seen that any other process which, at a higher connecting neuron, causes any increase or decrease of one of the processes in these arches must influence all others in a similar way. It is quite comprehensible, therefore, that ordinarily we experience either pleasantness or unpleasantness or neither, not both. But the nervous system is made up of such an enormous number of reflex arches and such a complicated hierarchy of nerve centers that doubtless nervous processes may go on somewhere within it and simultaneously other processes elsewhere so that a third class of processes may cause an increase of intensity in the currents of the first class and simultaneously a fourth class of processes a decrease of intensity in the currents of the second class. Thus pleasantness and unpleasantness do not necessarily exclude each other. But owing to the generally prevailing tendency of centralization of nervous function there will be, as a rule, at any moment either pleasantness without unpleasantness or unpleasantness without pleasantness, or neither. To describe pleasantness and unpleasantness as positive and negative quantities seems to the present writer pure speculation which arbitrarily disregards all introspective evidence to the contrary.

7. *Emotions and Pleasantness-Unpleasantness.*

It follows from our theory that the more nervous activity, that is, the more numerous and widely distributed the nervous currents, the more chances there are for intense feelings of pleasantness and unpleasantness. A good example of a wide distribution of the currents over the nervous system is an emotion of an adult human being. The consequence is, on the one hand, the complexity of organic sensation so characteristic of an emotion; on the other hand, the intensity of the pleasantness experienced, or unpleasantness, or both. The former has been most lucidly described by Lange, most successfully applied to psycho-

logical theory by James. The latter consequence, however, has never been clearly understood. The fact that pleasantness and unpleasantness are almost invariably and in great intensity found in emotion has led to the deplorable confusion of psychological terminology, where 'feeling' sometimes stands for an unanalyzed complex of organic sensations, sometimes for the pleasantness-unpleasantness experience, sometimes for both. The present writer cannot help believing that many of the contradictory results of experimental work on feeling of recent years would have resolved themselves and given place to perfect clearness if both experimenters and subjects had worked on the basis of some such theory of pleasantness and unpleasantness as has been presented above.

To avoid misunderstanding it may be stated here expressly that, although emotions of grown human beings, according to our theory, must nearly always be accompanied by strong pleasantness and unpleasantness, our theory does not require that states of consciousness of the kind which some psychologists would call emotions, for example the consciousness of lower animals or small children, must inevitably be accompanied by pleasantness and unpleasantness.

8. *Attention and Pleasantness-Unpleasantness.*

Our theory throws some light on certain problems connected with the theory of attention. 'Interest' has been defined by some psychologists as acquired capacity for attention, as distinguished from strictly native capacity for attention. Other psychologists have defined interest as attention accompanied by pleasantness. If our theory of the nervous correlate of pleasantness and unpleasantness is accepted, both definitions have the same meaning. Imagine you are interested in the presidential election. You have heard the dinner bell and are rising from your chair. The cover of a magazine strikes your eyes, on which you read the title of an article on candidates for the presidency. This interferes with your walking to the dining room and you experience a brief unpleasantness. Perhaps you decide not to take any dinner, but to find out immediately what the article has to say. While you are reading the paper, every

stimulation of your sense organs other than the sight of the printed pages is unable to reach its motor end, but must join and increase the intensity of the process of reading, because of your acquired capacity for reacting strongly upon words and sentences which have the meaning of politics. According to our theory you experience pleasantness. Thus we see that an acquired capacity of attention can result in unpleasantness at the moment when attention begins and must result in pleasantness as long as attention in the same direction continues. This continued pleasantness is much less likely to occur in a case of native attention; for the reflex arches which are the condition of native attention do not pass over the highest centers and thus are not to the same extent capable of forcing newly arising nervous processes to join them instead of running their own course. The nervous paths which are the condition of a highly developed acquired capacity for attention, are in contact with innumerable higher centers and are thus capable of forcing almost any newly arising nervous process to join and increase the habit process in question.

9. *The Causes of Action.*

Many writers on psychological topics have urged that it causes confusion in theoretical thought to speak of pleasantness and unpleasantness as causes determining our action. Fite, in the paper mentioned above, has strongly urged the necessity of this view denying causality to pleasantness and unpleasantness, in ethics, though unfortunately he has failed to make the necessary distinction between unpleasantness and the sensation of pain. According to our theory of their nervous correlate pleasantness and unpleasantness cannot be regarded as causes of action in the sense in which sensations and ideas are causes of action. The nervous correlate of a sensation is a nervous process starting at a sensory point, passing over a definite path of connecting neurons, and ending in a motor point of the body. The sensation (or perception, if it is a unified group of sensations) preceding the movement may justly be called the cause of the movement. If the nervous process passes over higher connecting neurons which have previously been excited from

different sensory points of the body we experience imagery. These images may justly be called the cause of the action, for this movement would not have taken place in response to this sensory stimulation if the nervous current had not taken this very path over higher connecting neurons. The fact, however, that a current, after becoming established, suddenly suffers an increase of intensity at an interior point of the course is not a necessary condition of a particular reaction, for, conditions in general being favorable, the same reaction can occur without a sudden increase of the nervous process. Therefore, if we regard pleasantness as the mental correlate of the increase in question, we gain clearness by abstaining from calling pleasantness the cause of the action. On the other hand, without this increase of intensity, the action might have suffered inhibition before it had been carried out in all its phases, so that, in this sense, the pleasantness may be called the cause of this action under these special circumstances of nervous activity, just as we often in daily life refer to pleasure as the cause of an action. However, those psychologists seem to have chosen the safer course who refrain from speaking of pleasantness as a cause of action, because thus they are induced to look for the more important, the ultimate causes of the particular response, for the sensory stimulation of the moment which leads to this response and the sensory stimulations of the past which have prepared the way for it; and looking for these ultimate causes in each particular case, they are more likely to discover them than those psychologists who are not in search of them, but are satisfied if they can assert that pleasure had something to do with the response.

10. *No Images of Pleasantness-Unpleasantness.*

Some psychologists have stated that 'feelings' cannot be imaged, revived, as sensations can. If by feelings are meant exclusively pleasantness and unpleasantness, we must agree with this view. According to our theory pure sensory impression occurs when a nervous process passes rather directly into a motor point of the body, imagery when it takes an indirect path over higher connecting neurons over which a different process

has previously passed from a different sensory point of the body. But the mere increase or decrease of a current, which according to our theory is the nervous correlate of pleasantness and unpleasantness, has no reference to directness or indirectness of the nervous path, and its mental correlate, therefore, cannot be expected to show any corresponding distinction.

II. *The Latest Product of Mental Evolution.*

Most psychologists hold that feeling is the most primitive form of consciousness, that sensation is the next higher stage of mental evolution, and ideation the highest. There may be truth enough in this, if by feeling is meant certain kinds of emotion which consist of vague undifferentiated sensation groups. But if by feeling is meant pleasantness and unpleasantness, the truth is probably that these represent rather the highest stage of nervous activity than the lowest. It is obvious that according to our theory of their nervous correlate pleasantness and unpleasantness are the highest product of mental evolution. They cannot exist in animals which are governed by ready-made and invariable reflexes. Only where, through mediation of higher nerve centers, variation of response becomes possible, can pleasantness and unpleasantness be experienced. And only in the highest animal, in man with his highly centralized nervous system, can they reach their highest degrees. That this is opposed to psychological tradition does not prove that it is wrong. The tradition has its origin in the lack of distinction between emotion on the one hand and pleasantness-unpleasantness on the other. The writer's own introspection seems to agree better with the consequence of the theory here developed than with the traditional view. His earliest childhood as remembered was characterized by primitive emotions of the purely instinctive type; but pleasantness and unpleasantness have made themselves felt the more strongly the more his education has advanced, the more his nervous processes have become able to interfere in the most manifold ways with each other. That a child laughs and cries more than an adult is true; but that a child experiences more pleasantness and unpleasantness does not follow. That the consciousness of the lower animals is a kind of primitive

emotion, made up of vague, unanalyzed complexes of organic and external sensations, may be admitted. Analyzed sensation and perception may be the next stage; but here gradually pleasantness and unpleasantness can make their appearance in mental evolution, reaching their highest development where the ideational processes attain their highest development, in the adult educated man.

Someone might raise here the question: If pleasantness and unpleasantness can not be 'imagined,' how can you 'remember' that they were less intense in childhood than in adult life? The answer to this question is this: I can know by memory that certain experiences of my present life are very much like those rather simple experiences of my childhood, and that other experiences in my present life are incomparably more complicated than any which ever occurred in my childhood. Now, if I know that the latter, the more complicated experiences, are, as a rule, distinguished by the most intense pleasantness and unpleasantness, I have a right to conclude that childhood is comparatively poor in pleasantness and unpleasantness.

The question may also be asked, how pleasantness and unpleasantness, if it is true that they are not the causes of our actions, can nevertheless induce a person to sit down at his desk and write a treatise about them. Here it must be understood that their causality has not been absolutely denied, that it has merely been held that their causality is a less direct one than that of sensations and images, and that, as a rule, we obtain a clearer insight into the causal connections in mental life by disregarding pleasantness and unpleasantness as causes than by using them as an ever-ready explanation for any actions whose origin is unknown.

SUMMARY.

By a study of the theories of various writers on pleasantness and unpleasantness we convinced ourselves of the great need for clearness in this field of psychology. In order to obtain this clearness, we found it necessary to develop a definite theory of nervous function. We could not develop this without first making a definite hypothesis as to the structural arrangement

of the elements of which the nervous system is composed. Thus we were enabled to advance a theory of the relation between consciousness and nervous function, in particular between pleasantness and unpleasantness and nervous function. This theory we applied to a number of specially important facts and found that these facts, otherwise rather isolated and not easily comprehensible, appear now as logical consequences of the theory, as an easily comprehensible system of psychological facts having this theory as their common basis.