CHAPTER III

THE FIRST SURE STEPS ALONG THE PATH OF A NEW INVESTIGATION [1]

(Read by the author on the occasion of his receiving the Nobel Prize, 1904.)

EFFECT OF APPETITE—PHYSIOLOGICAL EXPLANATION OF SOME "PSYCHICAL" FACTS—CONSTANCY OF THE REACTIONS ILLUSTRATED BY EXAMPLES—DIFFERENCES BETWEEN CONDITIONED AND UNCONDITIONED REFLEXES—SIGNALS—OUR PSYCHICAL CONTENT REMAINS A MYSTERY.

DURING the study of the gastric glands, I became more and more convinced, that the appetite acts not only as a general stimulus of the glands, but that it stimulates them in different degrees according to the object upon which it is directed. For the salivary glands the rule obtains that all the variations of their activity observed in physiological experiments are exactly duplicated in the experiments using a psychical stimulation, *i.e.*, in those experiments in which the stimulus is not brought into direct contact with the mucous membrane of the mouth, but attracts the attention of the animal from some distance. Here are examples of this. The sight of dry bread calls out a stronger salivary secretion than the sight of meat, although the meat, judging by the movement of the animals, excites a much livelier interest. On teasing the dog with meat or other foods, there flows from the submaxillary glands a concentrated saliva rich in mucus (lubricating saliva) ; on the contrary, the sight of a disagreeable substance produces from these same glands a secretion of very fluid saliva which contains almost no mucus (cleansing saliva). In brief, the experiments with psychical stimuli represent exact miniatures of the experiments with physiological stimulations by the same substances.

Thus, psychology, in relation to the work of the salivary glands, occupies a place close to that of physiology. And even more! On first view the psychological explanation of the activity of the salivary glands seems to be as incontrovertible as the physiological. When any object from a distance attracting the attention of the dog produces a flow of saliva, one has ground for assuming that this is a psychical and not a physiological phenomenon. When, however, after the dog has eaten something or has had something forced into his mouth, saliva flows, it is necessary to prove that in this phenomenon there is actually present a physiological cause, and not only a purely psychical one which, owing

[1] In 1904 Prof. Pavlov was awarded the Nobel Prize for his investigation on the digestive glands. In his lecture delivered on that occasion in Stockholm (the Nobel *Vortrag*), he gave a résumé of his principal new achievements.—*Translator.*

to the special conditions, is perhaps reinforced. From the following experiment this conception is seen to correspond in a remarkable way with reality. Most substances which during eating or forceful introduction into the mouth produce a flow of saliva, evoke a secretion after severance of all the sensory nerves of the tongue similar to that which they evoked before this operation. One must resort to more radical measures, such as poisoning of the animal or extirpation of the higher parts of the central nervous system, in order to convince oneself that between a substance stimulating the oral cavity and the salivary glands there exists not only a psychical but a purely physiological connection. Thus we have two series of apparently entirely different phenomena. How must the physiologist treat these psychical phenomena? It is impossible to neglect them, because they are closely bound up with purely physiological phenomena and determine the work of the whole organ. If the physiologist decides to study them, he must answer the question, How?

Following the examples of the study of the lowest representatives of the animal kingdom, and naturally not desiring to abandon physiology for psychology—especially after an entirely unsuccessful trial in this direction—we chose to maintain in our experiments with the so-called psychical phenomena a purely objective position. Above all, we endeavoured to discipline our thoughts and our speech [2] about these phenomena, and not to concern ourselves with the imaginary mental state of the animal; and we limited our task to exact observation and description of the effect on the secretion of the salivary glands of the object acting from a distance. The results corresponded to our expectations—the relations we observed between the external phenomena and the variations in the work of the salivary glands appeared quite regularly, could be reproduced at will again and again as usual physiological phenomena, and were capable of being definitely systematised. To our great joy, we are convinced that we have started along the path which leads to a successful goal. I shall give some examples of the constant relations which have been established by the aid of this new method of research.

If the dog is repeatedly excited by the sight of substances calling forth a salivary secretion from a distance, the reaction of the salivary glands after each stimulation becomes weaker and weaker, and finally falls to zero.[3] The shorter the intervals between separate stimulations, the quicker the reaction reaches zero, and vice versa. These rules are fully manifested only when the conditions of the experiment do not change. The identity

[2] It should now be evident to every one how important it was to adopt a new terminology for all the phenomena observed in order to get rid of the former psychical suggestions and their associations, and to introduce a purely physiological conception of all the facts.—*Translator.*

[3] For an illustration of this phenomenon see the record of the first experiment in chapter ii.—*Translator.*

of the conditions, however, need be only relative; it may be limited to those phenomena of the outer world with which had been associated the acts of eating or the forceful introduction of the corresponding substances into the animal's mouth; the variation of other conditions may remain without any effect. This relative identity can be easily attained by the experimenter, so that an experiment in which a stimulus is repeatedly applied from a distance gradually loses its effect, can be readily demonstrated in the lecture hall. If a substance, owing to its repeated employment as a distant stimulus, has become ineffective, the influence of other stimulating substances is not thereby annihilated: if milk from a distance ceases to stimulate the salivary glands, the distant action of bread remains clearly effective. After this has lost its influence by repetition, showing the dog acid will produce again a full effect on the salivary glands. These relations also explain the real meaning of the above-mentioned identity of the experimental conditions; every detail of the surrounding objects appears as a new stimulus. When a certain stimulus has lost its efficacy due to repetition, then its action after a certain interval of minutes or of hours is restored without fail.

The effect when temporarily lost, can be restored at any given time, however, by special means. If bread repeatedly shown to the dog fails to stimulate the salivary glands, it is only necessary to give it to the dog to eat and thereupon the full effect of the bread at a distance is at once restored. The same result is obtained when the dog receives some other food. And even more. When some substance producing a salivary secretion, for example, acid, is forced into the dog's mouth, the original distant effect of the bread previously lost is again fully manifested. In general, everything that stimulates the salivary glands restores the lost reaction, and the more fully, the greater has been their activity.

Our reaction can be inhibited by certain influences with the same regularity; if, for example, some stimulus which evokes in the animal a definite motor reaction acts on the eye or ear of the dog.

For the sake of brevity, I shall limit myself to the above mentioned material, and now pass on to theoretical considerations of the experiments. Our given facts can readily be included in a framework of physiological description. The effects we produced on the salivary glands from a distance may properly be considered and termed reflexes. It is impossible not to see, by close attention, that the activity of the salivary glands, when present, is always excited by some external phenomenon; *i.e.*, in the same way as the usual physiological salivary reflex, it is always produced by an external stimulus. The difference consists chiefly in that the usual reflex is determined by the stimulation from the mouth cavity, whereas the new reflexes are evoked by stimulation of the eye, ear, etc. A further essential difference between the old and the new

reflexes is that the former are constant and unconditional, while the latter are subject to fluctuation, and dependent upon many conditions. They, therefore, deserve the name of "conditioned."[4]

Considering the phenomena more closely, I can not fail to see the following distinction between these two kinds of reflexes: in the *unconditioned* reflex, those properties of the substance to which the saliva is physiologically adapted act as the stimulus, for example, the hardness, the dryness, the definite chemical properties, etc.; in the *conditioned* reflex, on the other hand, those properties which bear no direct relation to the physiological rôle of the saliva act as stimuli, for example, colour, form, and the like. These last properties evidently receive their physiological importance as *signals*[5] for the first ones, *i.e.,* for the essential properties. In their response one can not but notice a further and more delicate adaptation of the salivary glands to the external world. This is seen in the following case. We prepare to put acid into the dog's mouth, and the dog sees it. In the interest of the integrity of the buccal mucous membrane, it is highly desirable that before the acid comes into the mouth, there should be some saliva present; on the one hand, the saliva will hinder the direct contact of the acid with the mucous membrane, and, on the other hand, will serve to dilute the acid and thus weaken its injurious effect. But, of course, in reality the signals can have only a conditional significance, they are readily subject to change, as, for example, when the signalling objects do not come into contact with the mucous membrane. In this way the finer adaptation is based on the fact that the properties of the substances which serve as signals, now stimulate (*i.e.,* call out the reflex), now lose their exciting action. This is what occurs in reality. Any given phenomenon can be made a temporary signal of the object which stimulates the salivary glands, if the stimulation of the mucous membrane by the object has been once or several times associated simultaneously with the action of the stimulating phenomenon on another receptor surface of the body. We are now trying in our laboratory, with great success, to apply many such, and even highly paradoxical, combinations.

On the other hand, closely related and stable signals can be deprived of their stimulating action if they are often repeated without bringing the corresponding object into contact with the mucous membrane. If any food is shown to a dog for days or weeks without giving it to the

[4] Conditional (*ooslovny*) and not conditioned is Prof. Pavlov's term, but as *conditioned reflex* has become fixed in English usage instead of conditional reflex, we adhere to the term conditioned. In French and German translation, Prof. Pavlov's original term (conditional) has been preserved.—*Translator.*

[5] The conditioned stimuli provoking the conditioned reflexes are described here for the first time as *signals* of the qualities calling forth the salivary secretion.—*Translator.*

animal it finally completely loses its distant stimulating effect on the salivary glands. The mechanism of the stimulation of the salivary glands through the signalising properties of objects, *i.e.*, the mechanism of the "*conditioned stimulation,*" may be easily conceived of from the physiological point of view as a function of the nervous system. As we have just said, at the basis of each conditioned reflex, *i.e.*, a stimulation through the signallising properties of an object, there lies an unconditioned reflex, *i.e.*, a stimulation through the essential attributes of the object. Then it must be assumed that the point of the central nervous system which during the unconditioned reflex becomes strongly stimulated, attracts to itself weaker impulses arriving simultaneously from the outer or internal worlds at other points of this system, *i.e.*, thanks to the unconditioned reflex, there is opened for all these stimulations a temporary path leading to the point of this reaction. The circumstances influencing the opening or closing of this path in the brain are the internal mechanism of the action or of the inaction of the signallising properties of the objects, and they represent the physiological basis of the finest reactivity of the living substance, the most delicate adaptation of the animal organism, to the outer world.[6]

I desire to express my deep conviction that physiological research in the direction which I have briefly outlined, will be highly successful and will help us to make great advances.

Only one thing in life is of actual interest for us—our psychical experience. Its mechanism, however, has been, and remains, wrapped in deep mystery. All human resources—art, religion, literature, philosophy, historical science—all these unite to cast a beam of light into this mysterious darkness. Man has at his disposal one more powerful ally—biological science with its strictly objective methods. This study, as we all see and know, is making great advances every day. The facts and conceptions which I have given at the close of this lecture are typical of numerous trials to make use of systematic application of a purely naturalistic method of thinking in the study of the mechanism of the highest vital expression of the dog—this faithful and friendly representative of the animal world.[7]

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[6] This description of conditioned reflexes is practically the same as that given in chapter i (see footnote 7). The conditioned stimuli were admitted to be signals, arising from the simultaneous excitation by the important unconditioned and the unimportant conditioned stimuli, and the next logical test of this suggestion was its realisation. In the preceding chapter Prof. Pavlov states that such experiments have been performed successfully. A detailed description of these experiments will be found in the next lecture delivered about two years after the present one. *Cf.* footnote 3 of the next chapter.—*Translator.*

[7] Here one may notice that Prof. Pavlov intends to give an experimental basis for the comprehension of our psychical experience by investigating the mechanism of this complicated process in a higher animal—the dog.—*Translator.*

CHAPTER IV

SCIENTIFIC STUDY OF THE SO-CALLED PSYCHICAL PROCESSES IN THE HIGHER ANIMALS[1]

(Read in honour of Thomas Huxley, at the Charing Cross Medical School, London, October 1, 1906.)

ATTITUDE OF THE INVESTIGATOR—THE UNCONDITIONED SALIVARY REFLEX—THE NEW CONDITIONED REFLEX—RESULTS OF THE EXPERIMENTAL STUDY OF THE CONDITIONED SALIVARY REFLEX—REACTION OF WARNING AND SIGNALS—ELEMENTARY NATURE OF THE CONDITIONED REFLEX—CONDITIONS NECESSARY FOR ITS FORMATION—SIZE OF CONDITIONED REFLEX DEPENDENT ON INTENSITY OF STIMULUS—COMPLEX CONDITIONED STIMULI—CONDITIONED REFLEXES ARE LAW-OBEYING AND THEY CAN BE STUDIED OBJECTIVELY—MEDICINE AND PHYSIOLOGY.

THE subject of to-day's address, delivered in honour of Thomas Huxley, an eminent representative of natural science and a most energetic champion of that greatest biological principle (the doctrine of evolution), is the naturalistic investigation of the psychical processes in the higher animal.

I shall begin with an actual case which occurred in my laboratory a few years ago. Among my collaborators was a young doctor with an active mind capable of appreciating the joys and triumphs of investigation. Great was my astonishment when this loyal friend of science became profoundly disturbed on hearing of our plans to investigate the psychical activity of the dog in that same laboratory and by the same means which we had been using for the solution of physiological questions. All of our arguments were ineffective; he prophesied and hoped for only failure. The cause of this, as far as we could understand, was his idea that the psychical life of man and that of the higher animals was so individual and exalted that it not only did not lend itself to investigation, but would even be sullied by our rude physiological methods. Although this, gentlemen, may have been a somewhat exaggerated example, I believe it is characteristic and typical. In dealing with the highest vital phenomena, the fact must not be overlooked, that a systematic appreciation of natural science to the last limits of life will not

[1] In the expression "the so-called psychical process" the reader will see that the author has taken a new position. Now he considers all of his results as purely physiological. And he rejects definitely the further possibility of investigating subjective states. He begins to bring out a mass of evidence in favour of the purely physiological nature of his data. The artificial conditioned reflex treated of in this chapter strengthened his view, and gave new possibilities for thorough experimentation.—*Translator.*

be able to avoid misconception and opposition from those who are accustomed to regard these phenomena from another point of view and are convinced that this point of view is unassailable.

This is why I feel it obligatory first to explain exactly and clearly my point of view concerning the psychical activities of the higher animals, and secondly to pass from the preliminaries to the subject itself as soon as possible. I have referred intentionally to psychical activities as "so-called". If the naturalist hopes to make a complete analysis of the activity of the higher animals, he has not the right to speak of the psychical processes of these animals, and he can not so speak without deserting the principles of natural science. This is natural science—the work of the human mind applied to nature, and the investigation of nature without any kind of assumption or explanation from sources other than nature itself. Were the investigator to speak of the psychical faculties of the higher animals, he would be transferring ideas from his own inner world to nature, repeating the procedure of his predecessors who were accustomed, on observing nature, to apply to its inanimate phenomena their own thoughts, wishes and sensations. The naturalist must consider only one thing: what is the relation of this or that external reaction of the animal to the phenomena of the external world? This response may be extremely complicated in comparison with the reactions of lower animals, and infinitely complicated in comparison with the reaction of any inanimate object, but the principle involved remains the same.

Strictly speaking, natural science is under obligation to determine only the precise connection which exists between a given natural phenomenon and the response of the living organism to that phenomenon, or, in other words, to ascertain completely how a living being maintains itself in constant equilibrium with its environment. This assertion can hardly be contested, and is further supported by the fact that it receives daily more and more general acceptance in the investigation of the lower and intermediate stages of the zoological scale. The question is simply whether this rule is already applicable to the examination of the higher functions of the higher vetebrates. A serious endeavour to institute enquiries in that direction is, as it appears to me, the only reasonable answer to the question. I and my many collaborators began this work some years ago and we have recently devoted ourselves to it almost exclusively. I would now ask your attention to an account, first, of the most important results of this enquiry, which seem to me to be very instructive; and secondly, to an account of the inferences which may be drawn from it.[2]

[2] The hope stated in the next to the last paragraph of chapter i, as will be seen from the second paragraph from the end of this chapter, is now far in the future.

Our experiments have been performed exclusively on the dog, in which the particular reaction used was an unimportant physiologic process—the secretion of saliva. The experimenter was always working with a perfectly normal animal, *i.e.,* an animal which was not subjected to abnormal influences during the experiment. Exact observations on the work of the salivary glands could be made at any moment by means of a simple method. Saliva flows, as we all know, when something is given the dog to eat or is introduced forcibly into his mouth. Both the quality and the quantity of the saliva, under these conditions, is strictly dependent upon the quality and quantity of the substances brought into the dog's mouth. In this well-known physiological process we have before us a reflex. The idea of reflex action as a special elementary function of the nervous system is an old and established truism of physiology. It is the reaction of the organism to the external world, effected through the nervous system, by which an external stimulus is transformed into a nervous process and transmitted along a circuitous route (from the peripheral endings of the centripetal nerve, along its fibres to the apparatus of the central nervous system, and out along the centrifugal path until, reaching one or another organ, it excites its activity). This reaction is specific and permanent. Its specificity is a manifestation of a close and peculiar relation of the external phenomenon to the physiological action, and is founded on the specific sensibility of the peripheral nerve endings in the given nervous chain. These specific reflex actions in normal life, or to state it much more accurately, in the absence of abnormal vital conditions, are constant and unchanging.

The responses of the salivary glands to external influences are, however, not limited by the above-mentioned ordinary reflex actions. We all know that the salivary glands begin to secrete, not only when the stimulus of appropriate substances is impressed on the interior surface of the mouth, but that they also often begin to secrete when other receptive surfaces, including the eye and the ear, are stimulated. The actions last mentioned are, however, generally considered apart from physiology and receive the name of psychical stimuli.

We shall take another course, and shall endeavour to restore to physiology what properly belongs to it. These exceptional manifestations unquestionably have much in common with ordinary reflex action. Every time that such a flow of saliva begins it is attributable to the occurrence of some special stimulus among the external influences that may be

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Now the author disputes the right of psychology to handle those facts which are easily and successfully accessible to physiological investigation. As to the relation between his own work and psychology, his point of view is clearly expressed in the beginning of chapter xxiii.—*Translator.*

recognised. On very careful exercise of his attention the observer perceives that the number of spontaneous flows of saliva forms a rapidly diminishing series, and it is in the highest degree probable that those extremely infrequent flows of saliva, for which no particular cause is at first sight apparent, are, in reality, the result of some stimulus invisible to the eye of the observer. From this it follows that the centripetal paths are always stimulated primarily, and the centrifugal paths secondarily, with the interposition, of course, of the central nervous system. Now these are actually all the elements of a reflex action, the only missing points being exact data as to the operation of the stimulus in the central nervous system. Are we familiar with this last mechanism in the ordinary reflexes? Speaking generally, then, our phenomena are reflexes, but the difference between these newly recognised reflexes and the long-known ones is certainly immense, for they have been assigned to quite different departments of science. Physiology has, therefore, before it the problem of evaluating this difference experimentally, and of establishing the essential properties of the reflexes which have been newly recognized.

In the first place they arise from all the body surfaces which are sensitive to stimulation, even from such regions as the eye and the ear, from which an ordinary reflex action affecting the salivary glands is never known to proceed. It must be mentioned that usual salivary reflexes may originate not only from the cavity of the mouth but also from the skin and the nasal cavity; the skin, however, produces this effect only when it is subjected to some destructive process such as cutting or erosion by caustics, while the nasal cavity produces this effect only through the contact of vapours or gases, such as ammonia, which cause local irritation, but never through the agency of usual odours. In the second place, a conspicuous feature of these reflexes is that they are in the highest degree inconstant. All stimuli applied to the mouth of the dog unfailingly give a positive result wtih reference to the secretion of saliva, but the same objects when presented to the eye, the ear, etc., may sometimes be efficient and sometimes not. In consequence only of the last-mentioned fact have we provisionally called the new reflexes "conditioned reflexes," and for the sake of distinction we have called the old ones "unconditioned".

The further question naturally arose whether the conditions which determine the occurrence of the "conditioned reflexes" could be investigated, and whether a complete knowledge of the conditions would make it possible to impart to these reflexes a character of constancy. This question must be regarded, it seems to me, as answered in the affirmative. I will remind you of some well-established laws which have already been published from our laboratory. Every conditioned stimulus becomes

totally ineffective on repetition.[3] The shorter the interval between the separate repetitions of the conditioned reflex the more quickly is this reflex extinguished. The extinguishing of one conditioned reflex does not affect the operation of the others. Spontaneous restoration of extinguished conditioned reflexes does not occur until after the lapse of one, two, or more hours, but there is a way in which our reflex may be restored immediately. All that is necessary is to obtain a repetition of the *un*conditioned reflex, as, for instance, by pouring a weak solution of acid into the dog's mouth and then either showing it to him or letting him smell it. The action of the last-mentioned stimulus, which was previously quite obliterated, is now restored in its full extent. The following fact can be regularly observed: If for a long time, such as days or weeks continuously, a certain kind of food is shown to the animal without it being given to him to eat, it loses its power of stimulating from a distance,* that is, its power of acting from the eye, the nose, etc. These last-mentioned facts show plainly the close connection which exists between the stimulant effects of various properties of the substance—namely, the effects of the properties which excite secretion of saliva when the substance is in the mouth—and the effects of other properties of the same substance acting upon other receptive surfaces of the body. This material gives us the ground for assuming that the conditioned reflex in some way originates owing to the existence of the unconditioned reflex. And at the same time we may perceive the main features of the mechanism which gives rise to the conditioned reflex. When an object is placed in the mouth of the dog, some of its properties excite the simple reflex apparatus of the salivary glands; and for the production of our conditioned reflex that action must synchronise with the action of other properties of the same object influencing other receptive regions of the body whence the excitation is conveyed to other parts of the central nervous system. Just as the stimulant effects due to certain properties of an object placed in the mouth (unconditioned reflex) may coincide with a number of stimuli arising from other objects, so all these manifold stimuli may by frequent repetition be turned into conditioned stimuli for the salivary glands. Such stimuli may arise from the man who feeds the dog or who forcibly introduces certain articles into the dog's mouth, or they may owe their origin to the general environment in which this takes place. For this reason the above-mentioned experiments, by which the laws of the conditioned reflexes must be determined, require for their performance a well-trained experimenter who can really investigate only the action of the given conditioned stimulus or a definite

[3] For an illustration of this phenomenon see record of the first experiment in chapter ii.—*Translator.*

* Experiments made by Tolochinov and Babkin.

number of such stimuli, without unconsciously introducing new stimuli with each successive repetition. If this last condition is not realised the laws in question will naturally be obscured. It must be remembered that in feeding a dog or forcing something into his mouth, each separate movement and each variation of a movement may by itself represent a conditioned stimulus. If that is the case, and if our hypothesis as to the origin of the conditioned reflex is correct, it follows that any natural phenomenon chosen at will may be converted into a conditioned stimulus. This has, in effect, been proved to be true. Any visual stimulus, any desired sound, any odour, and the stimulation of any part of the skin, either by mechanical means or by the application of heat or cold, have never failed in our hands to stimulate the salivary glands, although before they were all ineffective for that purpose. This was accomplished by applying the stimuli simultaneously with the action of the salivary glands, their action having been evoked by the giving of certain kinds of food, or by forcing certain substances into the dog's mouth. These artificial conditioned reflexes,[4] the product of our training, showed exactly the same properties as the previously described natural conditioned reflexes. As regards their extinction and restoration they followed essentially the same laws as the natural conditioned reflexes.[5] Thus we have the right to say, that our analysis of the origin of conditioned reflexes is proved by the facts.*

[4] The possibility of establishing these artificial conditioned reflexes was of great importance. First of all it proved that the circumstances which give rise to the conditioned reflex, as mentioned in chapter iii, footnote 4, are adequately explained by the proposed theory. Besides this, the intentional formation of conditioned reflexes made possible a more thorough and conscious experimentation.—*Translator.*

[5] Professor Pavlov says (*Activity of the Cerebral Hemispheres* (Russian) p. 49):

"Formerly we made a distinction between 'natural' and 'artificial' conditioned reflexes; 'natural' reflexes being those which appeared to be formed spontaneously as a result of the natural association of, for example, the sight and smell of food with the eating of food itself, or of the procedure of introducing acid or some rejectable substances with the acid or the rejectable substance itself, while 'artificial' reflexes were those which could be formed as a result of artificially associating with the food or rejectable substance, stimuli, which in the ordinary course of events, have nothing in common with food or the rejectable substance. At the present time, however, we know that there is not the slightest difference in properties between all these reflexes. I mention this fact here because the numerous experiments of the earlier period of our work were carried out with the 'natural' conditioned reflexes, and it is from these that I shall draw many examples in the present lecture. All the numerous artificial stimuli which we now use every day in our experiments were important to us at the time of those experiments because they provided easily controlled, exact, and regularly reproducible stimuli, and because they could be applied to check the correctness of our conception of the mechanism by which natural conditioned reflexes are formed. At present the artificial stimuli predominate in importance because of the vast field of research they have unfolded to us and because they came ultimately to provide the most important material for our investigation."

* Experiments made by Boldirev, Kacherininova and Voskoboinikova-Granstrem.

Now that so much has been adduced on the subject we may advance further than was possible at the outset in the understanding of conditioned reflexes. In the manifestations of nervous energy which have up to the present time been submitted to careful scientific examination (our old specific reflex), the stimuli with which we had to do were comparatively few in number, but very constant in their action, and there was abundant evidence of a constant connection existing between the external influences and definite physiological effects. Now, however, in another more complicated part of the nervous system we encounter a new phenomenon, namely, the conditioned stimulus. On the one hand, this nervous apparatus becomes responsible in the highest degree, *i.e.*, it is susceptible to the most varied external stimuli, but, on the other hand, these stimuli are not constant in their operation and are not definitely associated with certain physiological effects. At any given moment we find comparatively few circumstances favourable for these stimuli becoming active in the organism for a longer or shorter time and producing distinct physiological results.

The introduction of the idea of conditioned stimuli into physiology seems to me to be justified for many reasons. In the first place, it corresponds to the facts that have been adduced, since it represents a direct inference from them. In the second place, it is in agreement with the general mechanical hypotheses of natural science. In many kinds of apparatus and machinery, even of simple construction, certain forces can not develop their action unless at the proper time the necessary conditions are present. In the third place, it is completely covered by the ideas of facilitation (*Bahnung*) and inhibition, ideas which have been sufficiently elaborated in recent physiological literature. Finally, in these conditioned stimuli, looked at from the point of view of general biology, we have a most perfect mechanism of adaptation, or, what amounts to the same thing, a very delicate mechanism for maintaining an equilibrium with the surrounding medium. The body has the capacity to react in a sensitive way to the phenomena of the outer world which are essential to it, because all other phenomena of the outer world, even the most insignificant, coinciding even temporarily with the essential become their indicators or, as they may be called, their signalling stimuli. The delicacy of the reaction shows itself both in the production of the conditioned stimulus and in its disappearance when it ceases to be a proper signal. There must be assumed to exist at this point one of the chief mechanisms for further discrimination in the nervous system. In view of all this, it is permissible, I think, to regard the idea of conditioned stimuli as the fruit of previous labours of biologists, and to consider my present report as illustrating the result of this work on a most complicated subject. It would be unreasonable to attempt to

determine at present the limits of the immense field thus opened and to partition it. The following must be regarded as, and nothing more than, a provisional arrangement of material that has been collected, giving only the points indispensable for purposes of explanation.

There are reasons for considering the process of the conditioned reflex to be elementary, namely, a process which consists only in the coincidence of any one of the innumerable indifferent external stimuli with a state of excitation of a point in a definite part of the central nervous system. Now a path is established between the former indifferent stimulus and this given point. The first argument in favour of this hypothesis is the repeated occurrence of this phenomenon: the conditioned reflex may be obtained in all dogs, and it may be produced by all imaginable stimuli. In the second place, there is the certainty of its occurrence; under definite conditions it is reproduced inevitably. We see, therefore, that the process is not complicated by any other (and unknown) conditions. It may here be mentioned that various conditioned stimuli which had been rendered effective were applied at a distance, as from another room; the experimenter, who for the purpose of obtaining the conditioned reflex usually either gave the dog something to eat or put a substance of some kind into the dog's mouth, was not now in close proximity to the animal, but the result of the stimuli was, nevertheless, the same.

It has already been stated that every imaginable phenomenon of the outer world affecting a specific receptive surface of the body may be converted into a conditioned stimulus. After conditioned reflexes had been obtained from the eye, the ear, the nose, and the skin, it was a matter of interest to know what relation the cavity of the mouth had to the general question, and whether a conditioned reflex originated in the mouth. The answer to the inquiry could not be a simple one, because in this case not only the receptive surfaces for the stimuli of the conditioned and of the unconditioned reflex, but also the stimuli themselves were all brought together. Careful observations, however, have made it possible to separate the conditioned stimulus from the unconditioned stimulus even in this instance. When inedible, irritant substances were many times in succession forcibly introduced into the dog's mouth, we could observe the following facts:

If, for instance, a certain amount of acid was poured into the dog's mouth many times in succession, on each fresh repetition of this procedure, there was regularly a greater flow of saliva; the same thing was repeated on a series of successive days until a certain maximum was attained, whereupon for a considerable time the secretion remained constant. If the experiments were stopped for some days the quantity of saliva secreted became much less. This fact could be very simply

explained as follows. On the first administration of the acid solution the secretion of saliva depended principally, or even exclusively, on the unconditioned reflex which the acid caused, while the subsequently occurring increase in secretion pointed to a conditioned reflex gradually formed under the influence of the same acid, and having as its receptor surface also the mouth cavity.*

We will now consider the conditions which determine the formation of conditioned reflexes. This question taken comprehensively is naturally a vast one. The following account will serve to give you only a slight idea of the full compass of this vast subject.

Although there are great differences in the time required for the establishing of a conditioned reflex, some relations have been seen to exist. From our experiments it is evident that the intensity of the stimulus is of essential importance. We have some dogs in which the cooling or warming of a definite place on the skin acted as a conditioned stimulus for the salivary glands. A temperature of zero or 1° C. in an experiment repeated 20 or 30 times caused saliva to flow, whilst a temperature of 4° or 5° C. in an experiment repeated 100 times gave no effect whatever. Exactly the same thing occurs with high temperatures. Heat of 45° C. applied as a conditioned stimulus showed similarly no action after even 100 applications; a temperature of 50°, on the other hand, caused a secretion of saliva after from 20 to 30 applications.** In contradistinction to this we must state with regard to acoustic stimuli that very loud sounds such as the violent ringing of a bell did not, in comparison with weaker stimuli, quickly establish a conditioned reflex. It can be assumed that powerful acoustic stimuli call out some other important reaction in the body (*e.g.*, motor), which hinders the development of the salivary response.

There is another group of related phenomena which deserves mention. When an odour not naturally exciting the salivary reflex—that of camphor, for instance—is by means of a special apparatus diffused, this diffusion of the odour must be made to coincide 10 or 20 times with the action of the unconditioned stimulus, such as acid poured into the dog's mouth. But if some of the odouriferous material is added to the acid, the new odour after one or two administrations acts as a conditioned stimulus. It should be asked whether the important circumstance in this experiment is the exact coincidence in time of the conditioned reflex or something else.***

For the sake of brevity I will entirely omit the technical details, such as by what methods the conditioned reflexes are best obtained; whether

* Experiments made by Zelheim and Boldirev.
** Experiments made by Boldirev, Kasherininova and Voskoboinikova-Granstrem.
*** Experiments made by Vartanov.

with food or with non-food substances; how many times the various stimuli may be applied in a day; with what length of intermissions, and so on. Next in order comes the important question, What are the stimuli that the nervous system of the dog recognises as individual phenomena in the outer world? Or, in other words, What are the elements of a stimulus? With regard to this a good deal of evidence is in existence already. If the application of cold to a definite area of the skin (a circle having a diameter of from four to five centimetres) acts as a conditioned stimulus for the salivary glands, the application of cold to any other portion of the skin causes secretion of saliva on the very first occasion. This shows that the stimulation by cold is generalised over a considerable part of the skin, or perhaps even over the whole of it. But the application of cold to the skin is very clearly distinguished as such from the application of heat and from mechanical stimulation. Each of these stimuli must be elaborated separately in order to give a conditioned reflex. Just as in the case of cold, the application to the skin of heat as a conditioned stimulus, also generalises itself. This is equivalent to saying that if an application made to one place on the skin stimulates the salivary glands, an application made to another cutaneous area will also produce a secretion of saliva. Totally different results were yielded by mechanical stimulation of the skin, such as rubbing with a coarse brush (by means of a special apparatus). When this treatment applied to a certain area of the skin had become converted into a conditioned stimulus, the same treatment applied to another place on the skin remained completely ineffective. Other forms of mechanical stimulation, such as pressure with a sharp or a blunt object, proved themselves less effective. Apparently the first mechanical stimulus formed only a small part of the latter.*

Stimulation by musical sounds or by noises is remarkably convenient for determining the discriminating or analytical faculty of the nervous system of the dog. In this respect the precision of our reaction is very great. If a certain note of an instrument is employed as a conditioned stimulus, it often happens that not only all the notes adjoining it but even those differing from it by a quarter of a tone fail to produce any effect.** Musical timbre (quality) is recognised with similar or even with much greater precision.[6] An external agent acts as a conditioned stimulus not only when it comes on the scene but also when it disappears, so that either its beginning or its end may be made the stimulus. Of

* Experiments made by Boldirev, Kasherininova and Voskoboinikova-Granstrem.

** Experiments made by Zeliony.

[6] In the following chapters the reader will meet with these phenomena under the name of *differentiation*. Chapter xvi is devoted especially to this subject, and it contains an analysis of the mechanism of the differentiation of various stimuli.—*Translator.*

course, a separate analysis has to be undertaken in order to explain the nature of such stimuli.*

We have hitherto spoken of the analytical ability of the nervous system as it presents itself to us in, so to say, a finished state. But we have now accumulated material which contains evidence of a continuous and great increase of this ability if the experimenter persists in subdividing and varying the conditioned stimuli. Here, again, is a new field of enormous extent.

In the material relating to the various conditioned stimuli, there are not a few cases in which can be seen an evident connection between the intensity of a stimulus and its effect. As soon as a temperature of 50°C. had begun to provoke a flow of saliva, it was found that even 30°C. had a similar but lesser effect. An analogous result may be observed in cases of mechanical stimulation. A diminished rate of rubbing with the brush (5 strokes instead of 25 to 30 strokes per minute) gives less saliva than the ordinary rate of rubbing, and accelerated rubbing (up to 60 strokes per minute) gives more saliva.

Furthermore, combinations consisting of stimuli of the same kind and also of stimuli of different kinds were tried. The simplest example is a combination of different musical tones, such as a chord consisting of three tones. When this is employed as a conditioned stimulus, the tones played in pairs and each separate tone of the chord produce an effect, but the pairs produce less saliva than the three together, and the notes played separately less than those played in pairs.** The case becomes more complicated when we employ as a conditioned stimulus a combination of stimuli of different kinds, that is, of stimuli acting upon different receptive surfaces. Only a few of such combinations have been provisionally experimented with. In these cases, one of the stimuli generally became a conditioned stimulus. In a combination in which rubbing and cold were employed the former was preponderant as a conditioned stimulus, while the application of cold taken by itself produced an effect hardly perceptible. But if an attempt is made to convert the weaker stimulus separately into a conditioned stimulus it soon acts energetically. If we now apply the two stimuli together, we have before us an increased effect resulting from the summation of stimuli.***

The following problem had for its object the explanation of what happens to an active conditioned stimulus when a new stimulus is added to it. In the cases that we examined we saw that the action of the previously formed conditioned stimulus was disturbed when a new stimulus of like kind was added to it. A new similar odour inhibited

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* *Ibid.*

** Experiments made by Zeliony.

*** *Ibid.*

the operation of another odour which was already a conditioned stimulus; a new musical note likewise impeded the action of a note employed as a conditioned stimulus, and just previously applied. It is not without interest, I think, to mention that we started with these experiments with another object in view. We were intending to form a new conditioned reflex with the aid of another conditioned reflex which had been previously formed. We accordingly experimented with combinations of dissimilar stimuli. Researches in this direction are well advanced. We have to discriminate between different cases. Some examples may be given. Scratching (or rubbing with a brush) may be a ready and effective conditioned stimulus. When we add to it the ticking of a metronome, applying both stimuli simultaneously, the scratching immediately loses its efficacy as a stimulant during the first applications (first phase); and this loss extends over some days but returns again, notwithstanding the addition of the metronome, and now our double stimulus has nearly the same effect as the scratching alone (second phase); later, scratching, when applied simultaneously with the metronome, ceases to act and the influence of this double stimulus now comes to an end altogether (third phase). When the glare of an ordinary electric lamp is added to scratching * which is a conditioned stimulus, the scratching at first produces exactly the same effect as before when it was without the lamp, but afterwards the combination of scratching and the luminous stimulus ceases to act.[7] Apparently a phenomenon of the same kind was observed when the action of other mechanical stimuli was experimented with instead of the scratching which had been made to play the part of a conditioned stimulus. In the first place, secretion of saliva was caused by pressure with a sharp as well as with a blunt object, but to a less degree than by scratching; on repetition, however, the effect of the pressure stimulus became progressively less, until finally, it altogether disappeared.

We may assume that a part of the stimulation by the sharp and blunt objects was identical with scratching, and that this component was responsible for the action of these objects during their first applications. But a part of the action was special; it led in the course of time to a destruction of the influence of the first. In these inhibitions we see the following phenomenon which in all experiments of this kind is

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* Experiments made by Vassilyev.

[7] As in both these cases the action of the new agent which checks the activity of the conditioned agent, must be especially elaborated by coincidence of the conditioned stimuli with this new agent (in the cases cited, metronome or light) and with lack of activity, *i.e.*, elaborated in a direction opposite to that of the conditioned stimulus, this new agent was designated as a conditioned *inhibitor* and the corresponding process as conditioned inhibition. The building up of this conditioned inhibition will be more clearly discussed in chapter viii.—*Translator.*

regularly repeated. After a conditioned stimulus had been applied together with another one which inhibited its action, the effect of the first one tried alone was greatly weakened, and sometimes even arrested completely. This is either an after-effect of the inhibiting stimulus which was added, or it is the extinguishing of the conditioned reflex because in the experiment with the added stimulus the conditioned reflex had not been strengthened by the unconditioned reflex.

The inhibition of the conditioned reflex is observed also in the converse case. When you have a combination of agents acting as a conditioned stimulus, in which, as has been already stated, one of the agents by itself produces almost no effect, then frequent repetition of the powerfully acting stimulus alone, without the other one, leads to a marked inhibition of its action, almost to the point of its annihilation. The relative magnitudes of all these manifestations of stimulation and inhibition are closely dependent on the conditions under which they originate.

The following is an example. We assume that the stimulus of scratching is acting as a conditioned reflex in the following manner: In the first place nothing but scratching was employed for 15 seconds, then acid was poured into the dog's mouth, scratching being continued up to the end of one minute. If you now apply scratching for a full minute, you get a copious secretion of saliva. Try to keep up this reflex, that is, continue the scratching for a second minute, and only then pour acid into the dog's mouth. If you do this several times in succession, the effect of the scratching will quickly diminish during the first minute and will ultimately cease altogether. In order that the scratching may regain its efficiency during the first minute, it is only necessary to repeat the experiment several times; indeed, its effect will be even greater than it was in the previous experiments.

We have observed a similar course of events also in the exact measurement of the inhibitory effect.

Finally, it may be mentioned that the attempt was made to form conditioned reflexes from the traces [8] of the latest remnants or after effects, both of a conditioned and of an unconditioned stimulus. This was accomplished by allowing a conditioned stimulus to act for one minute immediately before the unconditioned stimulus, or by even three minutes earlier. There was always an interval of a few seconds to several minutes between the stimuli. In all these cases the conditioned reflex

[8] *Trace reflexes* are the remnants of the excitations in the central nervous system. The traces of the excitation are supposed to function as signals for the setting in of the action. As stated in the text, these conditioned trace reflexes have quite peculiar properties. The reader will meet with references to them at several places throughout the lectures. For some possible explanation of the mechanism of this phenomenon see the next to the last paragraph in chapter vii.—*Translator.*

developed. But in the cases in which the conditioned stimulus was applied three minutes before the unconditioned one, and was separated from the latter by an interval of two minutes, we obtained a result which, although quite unexpected and extremely peculiar, always occurred. When scratching, for example, was applied to a certain spot on the skin as a conditioned stimulus, after it became active we found that scratching of any other place also produced an effect; cold or heat applied to the skin, new musical sounds, optical stimuli, and odours—all these had the same effect as the conditioned stimulus. The unusually copious secretion of saliva and the extremely expressive movements of the animal attracted our attention. During the action of the conditioned stimulus the dog behaved exactly as if the acid which served as the unconditioned stimulus had been actually poured into its mouth.*

It may appear that this phenomenon is of a different order from those with which we have hitherto been occupied. The fact is that in the earlier experiments at least one coincidence of the conditioned stimulus with the unconditioned one was necessary; but in these experiments, phenomena which had never occurred simultaneously with an unconditioned reflex were acting as conditioned stimuli. Here an unquestionable difference naturally comes to light, but at the same time there is seen an essential property of these phenomena which they have in common with the former ones, that is, the existence of an easily excitable point in the central nervous system, to which, as a result of its condition, are directed all the essential stimuli from the external world that affect the cells of the highest parts of the brain.

I now bring to a close my cursory and very incomplete summary of the data which have been obtained in this new field of research. Three characteristic features of this subject deeply impress the investigator. In the first place, these phenomena are easily accessible for exact investigation, being in this respect scarcely inferior to the ordinary physiological phenomena. I refer to the ease with which they may be repeated—beyond all expectation—to their uniformity under similar conditions of experimentation, and to the fact that they are suitable for experimental analysis. In the second place, there is the possibility of considering this subject objectively. The introduction of a few subjective considerations which we admitted now and again for purposes of comparison seemed on further reflection to be an act of violence or an affront to a serious intellectual endeavour. In the third place, the subject involves an unusual number of stimulating questions for the investigator.

Under what heading is the subject to be classified? To what part of physiology does it correspond? The reply to this question presents no difficulties. It corresponds partly to what was, in former days, the

* Experiments of Pimenov.

physiology of the special sense organs, and partly to the physiology of the central nervous system.

Up to the present time the physiology of the eye, ear, and other receptor organs has been regarded almost exclusively in its subjective aspect; this presented some advantages, but at the same time, of course, limited the range of enquiry. Investigation by the method of conditioned stimuli in higher animals avoids this limitation, and a number of important questions in this field of research can be at once examined with the aid of all the immense resources which experiments on animals place in the hand of the physiologist. Owing to the shortness of the time that remains it is impossible to give illustrations of such questions. The investigation of conditioned reflexes is even of greater importance for the physiology of the highest parts of the central nervous system. Hitherto this department of physiology, throughout most of its extent, has been cluttered with foreign ideas, borrowed from psychology, but now there is a possibility of its being liberated from such harmful dependence. The conditioned reflexes disclose before us the vast field of the relations and reactions of animals to nature; this is a subject of immense extent and one that must be treated objectively. The physiologist can and must examine these reactions, using in connection with them progressive and systematic removal of parts of the central nervous system in order that he may ultimately arrive at an exact knowledge of the mechanism involved. And here arise at once some urgent and practical questions.

Still one point remains. What relation is there between psychological data and the facts just described? What points of mutual correspondence are there? Who will occupy himself with these relations? and when? This relationship may be interesting even now, but it must be confessed that physiology has at present no serious reason for discussing it. Its immediate problem is to collect and to analyse the endless amount of objective material which presents itself. But it is plain that the conquest which physiology has yet to make consists for the most part of the actual solution of those questions which hitherto have vexed and perplexed humanity. Mankind will possess incalculable advantages and extraordinary control over human behaviour when the scientific investigator will be able to subject his fellow men to the same external analysis as he would employ for any natural object, and when the human mind will contemplate itself not from within but from without.

Must I say something about the relationship which exists between medicine and the subject of my address? Physiology and medicine are fundamentally inseparable. If the physician is in his actual practice, and even more important, in his ideals, a mechanic of the human organism, then inevitably every fresh discovery in physiology will sooner

or later increase his power over this extraordinary machine, his power to conserve and repair this mechanism. It is extremely gratifying to me that in honouring the memory of a great naturalist and man of science I am able to make use of ideas and facts which from this single successful point of view promises to throw light upon the highest and most complicated part of the animal mechanism. I am fully persuaded of, and boldly express my confidence in, the ultimate triumph of this new method of research and I avow it the more fearlessly because Thomas Huxley, who is an example to all of us, fought with rare courage for the freedom and the rights of the scientific point of view.

CHAPTER V

CONDITIONED REFLEXES IN DOGS AFTER DESTRUCTION OF DIFFERENT PARTS OF THE CEREBRAL HEMISPHERES [1]

(Read before the Society of Russian Physicians, St. Petersburg, and published in *Transactions of the Society of Russian Physicians*, 1907-1908.)

PAVLOV'S CONTROL EXPERIMENTS DO NOT CONFIRM THOSE OF BECHTEREV'S LABORATORY.

THE aim of this communication is to give a preliminary summary of the experiments, performed by my co-workers and myself, concerning the relation of the conditioned salivary reflex to the hemispheres. We consider the assertion of Dr. Belitsky, that the existence of conditioned salivary reflexes depends upon the presence of a certain cortical area, and after extirpation of this part of the hemispheres, all the conditioned reflexes disappear. The experiments of Dr. Tichomirov, described in his dissertation, and those of Dr. Orbeli completely refute the results of Belitsky. On the one hand, I am showing you the extirpated parts of the hemispheres in the dog containing the centres proposed by Belitsky, and on the other hand, Dr. Orbeli demonstrates before you a dog from which these centres have been removed, and which, as we can see, gives a prompt and strong reflex to the sound of crushing dry bread. Orbeli repeated the same experiments on another dog with the same results.

After receiving negative results in the control experiments of Belitsky, Tichomirov repeated similar experiments of Dr. Gerver with a conditioned reflex of the gastric glands, and obtained also negative results. I carried out these experiments myself a second time and saw the same results as did Dr. Tichomirov. From the brain of my dog and from the protocols it could be seen that, notwithstanding the removal of part of the cortex four times as extensive as that removed by Gerver, conditioned reflexes of the gastric glands were, nevertheless, present

[1] Near the end of chapter i Pavlov says: "After having established the possibility of analysis and systematisation of our phenomena, we come to the following phase of the work: the systematic division and destruction of the central nervous system in order to see how the above established relations will be changed in this process." Prof. Pavlov intended to use for this purpose the researches of Bechterev's laboratories. But here he was wholly disappointed, as all this work Pavlov failed to verify experimentally. So he had to start anew with these questions. The first of these experiments were performed by Orbeli and Tichomirov and are described in chapters v and vi. They were made for the purpose of verifying the researches of Bechterev's laboratories (Belitsky, Gerver and Gorshkov).—*Translator.*

on the sixth day after removal of the imaginary centres of Dr. Gerver, and these reflexes remained for some days. The findings of our experiments leave no doubt that Dr. Gerver became a victim of a mistake based upon the illness of his dog after operation and a consequent loss of appetite.

In my laboratory nearly all parts of the cerebral hemispheres have been removed in stages, and conditioned salivary reflexes repeatedly tried. From these experiments I must conclude that there is no special part of the hemispheres on which, in a general sense, the existence of the conditioned salivary reflex depends.

But this does not exclude special relations of different parts of the hemispheres to the conditioned salivary reflexes. Tichomirov showed that the arc of various conditioned reflexes in certain of its parts is located in the cerebral hemispheres. Artificial conditioned reflexes to the salivary glands from the skin disappeared completely and could not be re-formed if the part of the cortex corresponding to the so-called motor region was removed. Similarly, on removal of the occipital lobes, the natural optical reflex to the salivary glands disappeared. Other conditioned salivary reflexes persisted, and even new ones could be formed. The same relations have been seen in other dogs in our laboratory, besides those described in the thesis of Dr. Tichomirov. From our experiments we see that for the building up of the conditioned reflexes certain cortical connections from various specific receptors are necessary—from the eye, the ear, the nose, the skin. There is ground for assuming that the same is true for all other conditioned reflexes. Thus we have the right to state that: *the cerebral hemispheres are the organ of conditioned reflexes.*

Finally we may add that in our material there is no indication for belief in the existence of parts of the hemispheres especially engaged in the building up of conditioned reflexes (other than particular regions containing the various paths from specific receiving surfaces), *i.e.*, centres corresponding to the so-called association centres do not exist. A definite conditioned reflex disappears forever only when there are removed definite regions including the cortical conductors from its specific receptor organ.

CHAPTER VI

THE CORTICAL TASTE CENTRE OF DR. GORSHKOV

(Abstract from a lecture, read before the Society of Russian Physicians, and published in *Transactions of the Society of Russian Physicians*, 1907-1908.)

In 1901 Dr. Gorshkov inferred that the taste centre is situated in the frontal region of the brain. After the bilateral removal of these cortical gyri of the dog, according to Dr. Gorshkov, the animal quietly eats meat covered with salt, citric acid, or quinine, or meat soaked in the following solutions: salt 32 per cent, acid 9.5 per cent, or 5 per cent quinine. Dr. Tichomirov, repeating these experiments, could not obtain the same results. I also removed in a dog the same parts on both sides of the brain as Gorshkov; and could not see any loss of taste. It is evident that the inference of Dr. Gorshkov is a result of prejudice and of inexact observations. For example, Dr. Gorshkov drew his conclusions from operated dogs which died two or three days after the operation. And his experiments on dogs operated on one side of the brain, who "quietly ate with the opposite side of the tongue" meat mixed with vegetable substances mentioned above, shows that he is throughout fantastic.

CHAPTER VII

MECHANISM OF THE HIGHEST PARTS OF THE CENTRAL NERVOUS SYSTEM AS SHOWN FROM THE STUDY OF THE CONDITIONED REFLEXES [1]

(Read before the Society of Russian Physicians, and published in *Transactions of the Society of Russian Physicians*, 1908-1909.)

DIFFERENCE BETWEEN UNCONDITIONED AND CONDITIONED REFLEXES—TEMPORARY NATURE OF THE CONDITIONED CONNECTIONS, AND THE POSSIBILITY OF AN INFINITE NUMBER—COLOR BLINDNESS IN THE DOG—CONCENTRATION OF INDIFFERENT STIMULATIONS —IRRADIATION.

Six or seven years ago, with my collaborators, I made the first attempts to subject the entire nervous activity of the higher animals (of the dog) to an objective investigation, excluding absolutely any conjectures concerning the activity of the experimental animals based on a comparison with our internal world. From our point of view all nervous activity of the animal could be considered as a reflex activity of one of two forms —the usual reflex, which had previously been studied for many decades, and which we called an *unconditioned* reflex, and a second, new reflex which embraces the whole remaining nervous activity, and which we designate as *conditioned.*

At present, we can state with assurance that our experiment has been fully justified by the facts obtained; for the scientific material which our method has produced grows steadily and falls naturally into a certain system. These facts allow us, on the one hand, to systematise to a certain degree the process of the highest nervous activity, and on the other hand, to throw light upon some general, but real points in the mechanism of this function.

The organ upon whose activity in our experiments the different influences of the outer world are brought to play, is the salivary gland. A group of definite external stimulating agents, acting from the oral or nasal cavities or from the skin, were seen to call forth the usual reflex activity of the salivary glands—an activity which we called the unconditioned reflex. All external stimuli from these same receptors, and also from the eye and the ear, which are first directed to the receptor centres of the cortex, and from here into the medulla oblongata, provoke other reflexes—the *conditioned* reflexes. The paths along which

[1] It is to be noticed that at this stage of the investigation Pavlov selected from the multitude of facts confronting him the four most general features of the work of the cerebral hemispheres. They are discussed in this chapter, and the general scheme stands unchanged up to the present.—*Translator.*

the excitation of the first order travels, are fixed, and are always, under the circumstances of normal life, open and permeable. The paths for the excitations of the second group are paths which are formed under certain conditions of life; under other conditions, they are closed and impassable; thus these latter paths are now open, now obstructed. In this second group we have to do consequently with a *temporary coupling or connection* of different conduction paths, and this we must consider as a fundamental activity of the highest parts of the central nervous system, as a central point in its mechanism.

Any external stimulus, if only capable of being transformed on the body surface of the dog into a nervous process can, according to our experiments, be conducted to the salivary glands by means of the higher parts of the brain, thus becoming their stimulus. In this fact lies the second important point of their mechanism—the *universality of possible connections* in the higher departments of the central nervous system. The single fact which apparently contradicts this generalisation, is that up to this time we have not been able to form conditioned salivary reflexes by means of different refracted rays of light (*colours*). But we have good reason to consider this as not a conduction. Stated exactly, this fact signifies only that the generally accepted opinion about the dog, *viz.,* that he reacts to the different wave lengths of light, or, subjectively speaking, distinguishes between colours, is not based on experiment, but is a prejudgment arising from a superficial analogy with man.

The third point in the mechanics of this action which we have analysed is manifested in the nature of the method itself, by means of which the conditioned reflexes are formed. In order to make a stimulus for the salivary glands from any phenomenon acting on the receptor surfaces of the dog, it is necessary that the action of this phenomenon on the dog should occur simultaneously with the unconditioned reflex of the salivary glands provoked by the introduction of food or of some inedible stimulating substance into the mouth of the animal. From this fact it is evident that if very strongly excited foci arise in the nervous system (in the given case, in the salivary reflex centre), the formerly indifferent stimuli from the external world, acting on the receptors and thus exciting the receiving centres of the cortex, are conducted toward these strongly excited foci; in this way the impulses concentrate and open a path leading to these foci. This fact can be designated as the *mechanism of concentration* of direction of indifferent stimulations.

Finally, the fourth part of this mechanism. This is to be found in facts relating to a special group of conditioned reflexes. They have been investigated in our laboratory by Dr. Pimenov. If some external

agent, which we intend to use as a conditioned stimulus of the salivary glands, does not coincide exactly with the unconditioned salivary reflex but always precedes it, and if the end of its action is separated from the beginning of the unconditioned reflex by a certain interval (in the experiments of Pimenov by a pause of two minutes), then the following happens. When the conditioned reflex has thus been elaborated, there also act as stimuli various other external phenomena, and these stimulations by the external phenomena develop only gradually in a certain definite order. If, under such conditions, the original mechanical irritation of a certain skin area has been made a stimulus of the salivary glands, then also the mechanical stimulation of other skin areas begins at first to call out the salivary reflex, contrary to the law of specificity of the ordinary from mechanical stimulation of the skin-conditioned reflexes. Afterwards thermal skin stimulations show this effect, and finally the irritation of other body surfaces, for example, of the nose, the eye and the ear. The internal mechanism of this fact can be understood thus: A stimulation entering the cerebral cortex which is not directed to a certain active nervous point begins to spread and disperse itself over the surface of the brain. If now a strongly excited point arises later, it will attract to itself cortical stimulations not only from the point originally irritated, but from all other points over which the stimulation had gradually spread. This is the law of dispersion, of irradiation of the stimulation in the cerebral cortex.[2]

Obviously, the formulation of these four points in the mechanism of the highest parts of the central nervous system must in many respects be considered provisional.

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[2] For a more detailed study of these processes of "irradiation" and "concentration," see chapter iv.—*Translator.*

CHAPTER VIII

FURTHER ADVANCES OF THE OBJECTIVE ANALYSIS OF COMPLEX NERVOUS PHENOMENA, AND ITS COMPARISON WITH THE SUBJECTIVE CONCEPTION OF THESE PHENOMENA [1]

(Based on the experiments of Dr. P. N. Nikolaev. Read before the Society of Russian Physicians, and published in *Transactions of the Society of Russian Physicians*, 1909-1910.)

ALL NERVOUS ACTIVITY IS A REACTION TO THE EXTERNAL WORLD BY MEANS OF UNCONDITIONED AND CONDITIONED REFLEXES—DETAILS OF AN EXPERIMENT WITH CONDITIONED REFLEXES—REFLEX OF SECOND ORDER AND COMPLEX CONDITIONED STIMULI—INHIBITION—DETAILS OF EXPERIMENT—DEDUCTIONS FROM THE EXPERIMENT—EXPERIMENTAL PROOF OF THE HYPOTHESIS—INHIBITION OF INHIBITION—DISCUSSION OF THE MEMBERS OF THE COMPLEX STIMULUS—COMPARISON OF THE SUBJECTIVE AND OBJECTIVE ANALYSES OF THE EXPERIMENTAL FACTS—PHYSIOLOGY AND PSYCHOLOGY.

THIS address has to do with the so-called conditioned reflexes—the objective investigation of the activity of the central nervous system of the dog. I shall ask you to recall some of the fundamentals of this study. From the standpoint of objective research, we hold that all the nervous activity of the dog, without reservations, is a reflex activity, a reaction of the animal to the external world effected through the nervous system. In this reaction, we can distinguish two kinds of reflexes. The simple and well-known reflex, which we call "*unconditioned,*" is one in which certain phenomena of the external world are associated with definite responses of the organism through a constant and unchanging connection in the central nervous system. For example, if a mechanical body impinges on the eye of an animal, it is always followed by a defensive movement of the eyelid, or every time a foreign body enters the larynx

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[1] Even at this stage of the investigation Pavlov was aware that in this fine work of the hemispheres one must take into consideration the individual peculiarities of each different nervous system. In chapters xxxv and xxxviii one will find more facts on this point. The matter is discussed systematically in chapter xvii of Pavlov's *Activity of Cerebral Hemispheres.*

In special experiments it proved really to be true that the stimulus which often coincides in time with the state of inhibition in a point of the hemispheres becomes able, when applied, to produce this state of inhibition.

The extinction of the conditioned reflex is considered as brought about by a process of inhibition. The production of this inhibitory process is hindered by every extraordinary or new agent added to the extinguished conditioned reflex; so, for lack of inhibition, the conditioned reflex becomes again efficient. This process, viewed as a lifting of the brake (inhibition), received the name "dis-inhibition." In chapter x, describing the first cerebral mechanism, and in chapter xi, there are given examples of dis-inhibitors.—*Translator.*

and irritates it, coughing results. From these old reflexes we can differentiate a new group in which the connection of the external phenomena with the responsive reaction of the organism has only a temporary character. This connection forms under only certain conditions, continues only in the presence of certain conditions, and disappears under definite conditions. Thus we distinguish between *constant* and *temporary* reflexes. In this way can we comprehend and understand many complicated relations of the dog to the outside world as *temporary reflexes.*

At present, as shown by numerous reports already presented, our knowledge concerning the conditioned reflex is based on a great body of facts, which, we can assert without exaggeration, multiply themselves each day. Besides, the appearance of the rules and laws which embrace and unite this multitude of facts insure for our investigation an uninterrupted progress.

Here we would present for your consideration an instance of the complex nervous activity of the dog, an instance in which, as we think, the analysis is deeply penetrating and yet as a matter of particular interest, preserves, despite this depth, a great accuracy. In order to render perfectly clear everything that I have to say I shall report the concrete case of a dog upon which we performed the experiments, and trace the results from the very beginning. It is necessary to add that some of the facts of this exposition, obtained from this dog, were also obtained from many other dogs; and the last observation which I shall present, and which forms the new material of this report, was repeated on a second dog with exactly the same results. Consequently the facts in this address cannot be considered as accidental.

A light (L), in the tables, has been made a conditioned stimulus for the salivary glands by means of the food reflex. This is accomplished in the following manner. The dog is put into a dark room, and at a certain moment a bright electric light is switched on. We wait for a half minute, and then give the dog food and allow it to eat for a half minute. This procedure is repeated several times. Finally the electric light, which at first was an indifferent agent for the animal, and had no relation whatever to the function of the salivary gland, owing to repeated coincidence of eating with salivary activity, becomes endowed with the property of acting as a special stimulus for the salivary gland. Every time the electric light appears we have a salivary secretion. Now we can say that the light has become a conditioned stimulus of the gland. The activity of the salivary gland in such a case serves as a simple index of the reaction of the animal to the external world. This reflex gradually grows until it finally attains a certain limit, in the present case, ten drops of saliva in half a minute. We now add to the light a definite tone (of

about 426 vibrations per second); the simultaneous action of the two, as you will see in the tables, is represented by L plus T. The combination of light and tone lasts a half minute. This combination of stimuli is never accompanied by feeding. For the first few applications of this combination there is no change in the original effect of the light, *i.e.*, the light plus tone gives the same salivary secretion as the light alone did (ten drops in half a minute). I wish to emphasise that this combination is never accompanied by food. We ask ourselves, however, the following question: Although apparently there is no outward change, may it not be possible that there has taken place in this process some intrinsic transformation? Has not the tone which we have joined to the light and which formerly had no relation to the salivary gland become something other? And after four or five applications of this combination (without feeding), the tone had acquired the property of acting as a stimulus of the salivary secretion. It is true the effect was very small, only one or two drops. But what does this signify? Why has the tone become a stimulus? Why has the tone which has never been accompanied by feeding taken on the character of a stimulator? It is evident that the tone acquired its exciting effect by being applied simultaneously with the light, and it has actually gone through the same process as occurred when the light received (from its association with eating) its stimulatory effect on the salivary secretion. In the action of the tone we see the action of a new conditioned reflex, and as in the given case the effect of the tone came about owing to its coincidence with a conditioned stimulus (light), and not to coincidence with an unconditioned stimulus (food), this new stimulator (tone) can be designated as a stimulus of the second order, and the new reflex as a *reflex of the second order.*

This effect, it is necessary to note, is in most cases very weak, only one or two drops, very transitory, and not fixed. If the experiments are continued for some time, the tone will lose its action. This period comprises the *first phase* of the different changes through which the tone effect in the combination passes. The secretory action itself is so small and it requires such exact conditions for its manifestation, that doubt may arise even as to its very existence. But there is a circumstance which greatly facilitates the control of this experiment. Among the experimental dogs one finds special types of nervous systems; in particular there are dogs with weak nervous systems in which this phenomenon is clearly expressed. This phase remains comparatively stable, so that the conditioned reflex of the second order in such dogs may last for weeks, and disappear very reluctantly.

So the first result of the combination (tone plus light), which is never accompanied by eating, consists in this; the tone also becomes a conditioned stimulus. Repeating this double stimulation ten to twenty

times and never supporting it by feeding we arrive finally at the next phase. If this combination during the first four to five applications gave the same effect as the light alone, then afterwards the action of this combination begins to decrease, and instead of ten drops, it produces eight, five, four, three, and finally no drops. So the light (L) alone yields ten drops, and the light plus tone (L + T), zero. This last state remains stationary; repeat this double stimulation as much as you will, you see no change. What does this mean? Is there some sort of internal mechanism at work? And if there is, can it be discovered, and by what means? Obviously, we must try the component elements of this double stimulation. It is not necessary to try the light, as we know that it always gives ten drops. There remains for us only to try the tone alone. We saw that the tone in the first phase gave one to two drops, but if we try it now, it gives nothing. How shall we explain this zero? There are two possible explanations: it can be either a true zero, that is, it may have no effect whatever, or it may have a negative value, *i.e.*, it may not only be indifferent but actively inhibiting. This problem must be solved, but how? We have a series of experiments which decide this question finally and absolutely. The tone is not zero in the combination (double stimulus); it has a negative value, it is actively inhibiting.

This can be shown in the following way. Let us take, besides the conditioned light stimulus, some other conditioned food reflex, for example, mechanical irritation of the skin, which also calls out salivary secretion. Now let us unite this scratching (skin irritation) with a tone. It was shown that the tone destroyed the effect of the scratching. From this one can see that the effect of the tone is not zero, but an active minus. It has become an inhibitory agent. Thus it is evident that if the tone is joined to some other conditioned stimulus, the action of this stimulus is destroyed.

On the basis of these facts we are convinced that at the foundation of our complex conditioned reflex there lies a definite internal mechanism. This mechanism consists in the following: If we join to a conditioned reflex any other indifferent stimulus, and then do not support this double stimulus by an unconditioned reflex (food), the new agent will pass through two phases of activity. At first, for a short time, the new agent appears as an active stimulus of the unconditioned action, but afterwards, in the second phase, it plays another rôle—that of an inhibiting agent.

The above statements were made by us some time ago. Now I shall pass over to entirely new facts. My collaborator, Dr. Nikolaev, who has just completed work on this problem, is responsible for them. I shall now present them to you, and analyse them. To the double stimulation of light plus tone, we add a third, a metronome (L + T + M in the

tables). This trio (L + T + M) is always followed by food, and we maintain the same time condition, *i.e.*, the trio is given alone for half a minute, and then it is given for another half minute accompanied by eating. Therewith is developed a very long and interesting series of phenomena. The gist of our report today is contained in the analysis of this picture, which is shown in Table I.

TABLE I

EFFECT OF THE TRIPLE STIMULUS
L + T + M

Flow of Saliva in Drops	*Number of Recurrences of the Same Result*
0	
0	2 times
2	once
4	16 times
6–9	5 times
10	16 times
10	22 times

This table represents the stimulating effect of our trio (L + T + M) and the separate periods of its action and the quantity of saliva. In the table zero occurred twice. This means that the influence of the triple stimulus was at first the same as that of the double stimulus, *i.e.*, zero. This obtained, however, in only the first two experiments. From the third experiment a change set in. In place of zero, the trio now gave two drops, and that only once; afterwards it began to give four drops, and this occurred sixteen times. So this first long period lasted sixteen days. Thus the triple stimulus on its fifth trial produced a definite salivary secretion, *viz.*, four drops. Now may we rightly ask, what does this mean? And what is its internal mechanism? and why did we receive precisely four drops and no more nor less? Our problem is now complicated because we have three agents, each one of which has a different significance. In order to explain the conjoint action of these three agents it is obviously necessary to try their action singly and also in various combinations.

As a result of these investigations, we obtained certain facts which lead us to a definite conclusion. We have three agents; from these it is possible to make seven combinations. Light, tone, and metronome each separately, light plus tone, light plus metronome, tone plus metronome, and finally light plus tone plus metronome. Now we must try out all these combinations, and the result will yield us some answer. We are already acquainted with three of these seven combinations. The light alone gives ten drops; the light plus tone, zero; light plus tone plus metronome, four drops.

TABLE II

L	= 10 drops
L + T	= 0
L + T + M	= 4
T	= 0
M	= 0
T + M	= 0
L + M	= 6

It must be expressly stated that all these combinations are repeated every day, and that they gradually become strengthened in their special effect. Now we must try out the other four combinations, which usually are not applied, and which we try only occasionally, for the purpose of making an analysis. The metronome alone is without any effect, also the tone alone, as well as the tone + metronome. The single effective combination we find to be the light + metronome. But we note from the beginning a certain peculiarity: the light + metronome yields six drops, but the light alone, ten drops. This fact may be explained in the following manner: the metronome becomes an inhibiting agent; for in the combination of the light and the metronome, the effect is smaller than from the light alone. Now we come to the conclusion that during the first period of the application of our trio, the metronome has taken on the rôle of an inhibiting agent, as the light in combination with the metronome gives less saliva than the light alone.

Now two questions arise: first, how does the metronome in this trio receive its inhibitory action? and secondly, how can the metronome, being inhibitory, produce a secretion of four drops of saliva in the triple stimulus? The first can be answered only hypothetically, because we have not, as yet, pertinent experiments. Our hypothesis is the following: when to the light + tone we add the metronome, and allow this trio to act for a half minute and follow it for the next half minute with feeding, then during the beginning of the period of the coincidence of the metronome with the light + tone, in the nerve cell of the animal there exists an inhibitory process. In this case the action of the metronome coincides with the process of inhibition in the nerve cell, and therefore it is quite natural that it should acquire the character of an inhibitory agent—the colour, so to speak, of the process with which it had been constantly involved.

In this instance a phenomenon appeared, analogous to that mentioned above when, in interpreting the mechanism of the double stimulation (L + T), we noted that the tone added to the light borrowed from the latter its stimulating action; so here also the process predominant in the nerve cell lent its own colour to the agent coinciding with it. Thus we must explain how the metronome has itself become an inhibiting agent

due to its coincidence with an inhibitory process. We cannot suggest any other explanation.

I repeat that this explanation is in the highest degree probable, but probability is one thing and fact another. Therefore, we decided to perform a series of new experiments in order to confirm our supposition. Thus we came to the decision of our second question: how can the metronome, which in the triple stimulus received its inhibiting action, have transformed the trio into a stimulating agent, now yielding 4 drops of saliva; *i.e.,* how has it become now a stimulator?

This effect might appear to us as entirely incomprehensible, if we had not exact data about a certain nervous process which we have analysed every day for many years. This is the so-called *inhibition of inhibition.* It consists in the following: If you have some conditioned stimulus, and if you add to this any other agent having a certain effect on the dog (for example, if the dog turns toward it), this agent will inhibit the conditioned stimulus. The inhibitory process is an habitual and well-known phenomenon in the physiology of the central nervous system. But also the following can be observed: if you, having to do with an inhibitory process in the nervous system, join to this inhibited stimulus some new extra agent, the inhibited stimulus now manifests its own effect. This fact may be understood thus: the new extra agent inhibits the inhibition, and as a result there is a freeing of the previously inhibited action, *i.e.,* a positive effect. If we take light, our conditioned active stimulus, and join to it an extra agent, for example, a whistle, the light effect is inhibited. But if, having extinguished the effect of the same light by repeating it without feeding, we now join to this inactive light some extra agent, the light will show its earlier stimulating effect. This is the phenomenon of inhibition of inhibition. The process of inhibition of inhibition is as often observed in the activity of the central nervous system as are the processes of stimulation and inhibition.

Now if this is true, the appearance of four drops of saliva after our triple stimulus (L + T + M = 4 drops) must be understood as follows: the metronome, having attained an inhibitory effect, acted on the nerve cell, which was itself involved in an inhibitory process, *i.e.,* the metronome inhibited the action of the tone, and in this way liberated from its inhibiting influence a part of the effect of the light. On the basis of the fact that the metronome is an inhibitory agent, and in consideration of certain definite processes of the nervous system, we must interpret this period of the action of our combination during which it gives 4 drops. In this period it appears that our newly added stimulus (metronome), falling on the soil of inhibition, inhibits only the inhibition, and liberates from its influence the conditioned stimulus (light).

Now we would call your attention again to Table I. You have seen that

sixteen of these experiments done with the triple stimulation yielded the same result. Further we have seen that on the twentieth trial, a change sets in, and the process passes over from the first phase to the following: the effect of the trio increases to 6, 7, 8, and 9 drops, and, in the twenty-fourth experiment, to 10 drops. Thus the effect of the trio becomes equal to the action of the light alone.

TABLE III

L	= 10 drops
L + T	= 0
L + T + M	= 10
T	= 0
M	= 4
T + M	= 4
L + M	= 10

Here in this Table III we find ourselves in the second period of the process. Now we must explain to what circumstance we owe the effect of the triple stimulus in producing 10 drops instead of the previous 4, and the significance of all the agents taking part in this effect.

Let us endeavour to make some analysis of this, *i.e.*, let us test the significance of all possible combinations. The following three are already known to us: light with its effect of 10 drops; L + T, zero; L + T + M, 10 drops. Further, it was proved that the tone remained zero, that the metronome now has an effect of 4 drops, and that the tone plus metronome gives also 4 drops; the metronome when joined to the light does not change the action of the latter, and consequently the metronome has lost its former inhibitory effect. Thus the metronome in the second phase passes over from the rôle of an inhibitor to the rôle of a stimulator of moderate strength. It itself gives 4 drops, and together with the tone it also gives 4 drops, and when joined to the light it gives the same effect as the light alone.

Here I must remark that when active conditioned stimuli are combined, there is never a summation of the individual actions in the combination. That is, if you have several conditioned stimuli acting in different degrees of strength, then the combination of them, one with the others, gives a quantity of saliva corresponding to the action of the strongest stimulus. In our case, the maximum quantity was given by the light, and therefore, in the combination with the metronome, the double stimulus gave exactly the same effect as the light alone.

Thus, in the triple stimulus we see a process analogous to that which we observed in the double stimulus, with only this difference, that the process occurs here in a reversed order. There we observed two consecutive phases; the first, when a newly added agent takes on the character of the conditioned stimulating process, and the second, when this new

agent is changed into an inhibiting agent, owing to the fact that it is never accompanied by food. A similar process is observed in the case of the triple stimulus: here we see that the new stimulus, the metronome, during the first period of the application of the trio, has become an inhibiting agent, having been influenced by that process which was at the given moment predominant in the nerve cell. With the continued application of the triple stimulus, owing to its being accompanied by eating, the metronome acquired a stimulating action. Consequently, we see that the same regular recurrence of the two phases has been repeated here.

Now arises the interesting question concerning the significance of the other combinations. You see that the tone alone always remained zero; notwithstanding the fact that the tone in the trio was accompanied by eating, it did not receive any stimulating action. This means that the tone during its presence in the trio did not become a stimulus. On the other hand, while in the trio it was not an inhibitory stimulus; for the metronome alone and the metronome in combination with the tone evoked the same 4 drops.

Thus you see that the rôle of the tone is an exceedingly interesting and peculiar one. Under different conditions the tone has a different effect; in the double stimulus, it acts as an inhibiting agent, and in the trio, it has no effect.

If we consider all the above facts, we come to the conclusion that we have to do with certain regularly recurring events, which bear a certain relation to one another. In other words we see the summated action of different agents, which under stated conditions come to have a definite plus or minus effect, and thus a certain *equilibration* among them is attained. That is, we have to do with some not yet clearly definable equilibrium of the nervous process. You see that our ciphers remained exact and constant, and that thereby each agent has a special and definite significance. If these phenomena were accidental, then our figures would be very fluctuant and confused. Our facts, however, were not at all of this character. This is the first logical account showing that we have really to do here with a definite equilibrium.

Another more direct proof appears from the work of Dr. Nikolaev. His comparison of figures revealed a certain definite relation, a mathematical connection one with the other. In Table IV you can see that the double stimulus (L + T) was never accompanied by food, and was strengthened in its rôle of a zero agent, and the triple stimulus (L + T + M), on the other hand, was always accompanied by eating and became reinforced in its rôle as a stimulator. What does all this imply? It shows that in order that these rôles may not be interchanged—that the double stimulus will always give zero and the triple stimulus 10 drops—

there must obtain definite mathematical relations between the repetitions of the combinations. Namely, the double stimulus which is not accompanied by eating must be applied exactly twice as many times as the trio because as soon as the trio began to be repeated more frequently, the double stimulus lost its *nil* effect, and became positive.

TABLE IV

Date	*Saliva*	*Number of trials and their order* L + T	*Number of trials and their order* L + T + M	*Ratio:* $\frac{L+T}{L+T+M}$
Jan. 21	0	28	14	= 2:1
Jan. 31	0	32	16	= 2:1
Feb. 3	2	35	18	< 2:1
Feb. 5	0	45	19	> 2:1
Feb. 12	0	63	26	> 2:1
Feb. 16	0	74	32	> 2:1
Feb. 26	0	85	40	> 2:1
Mar. 2	2	92	47	< 2:1
Mar. 4	0	100	50	= 2:1
Mar. 5	5	103	52	> 2:1
Mar. 10	0	122	56	= 2:1
Mar. 13	0	120	60	= 2:1
Mar. 17	0	126	63	= 2:1

From the above table it is evident that every time the double stimulus was repeated twice as many times as the trio its action was always zero. Only under such conditions could the inhibiting agent manifest its effect. But as soon as the trio was repeated oftener than the double stimulus, the relation failed, the inhibiting action of the tone became weaker and the double stimulus came to have a positive effect, as shown in the experiments for Feb. 3, Mar. 2, and Mar. 5.

Here you see that for these combinations to maintain their definite significance, there must be preserved their mathematical relations, *viz.*, that the double stimulus must be repeated exactly twice as many times as the trio.

Such are the facts to which we would call your attention. We undertook an analysis of three agents, and we saw that the action of the agents developed with certain regularity. There appears the law of the action of the newly added agent; this agent passes through two phases, and finally a certain equilibrium was always reached in the nervous system, a definite plus or minus influence of the agents one upon another.

After these instructive facts were obtained, we desired to know whether the investigation of the corresponding nervous phenomena could be made with similar exactitude by means of subjective analysis. For this purpose I sought to acquaint myself with the conditions—I addressed myself to books on the subject. I did not find in the books what I was

looking for, perhaps because it is difficult to become a specialist in a short time. Therefore I turned with the following question directly to specialists. To what facts of subjective psychological analysis do our facts correspond, and how are they to be analysed? Unfortunately, in this, as well as in many foregoing cases, my trials were unsuccessful. Some answers were received from which it was impossible to extract anything positive, and this is easily understood. The comparison of the results obtained by objective analysis of the complex nervous phenomena with the results of subjective research met with extraordinary difficulties of two sorts. All our reasoning had to do with facts obtained by a strictly objective method, and are of a special character; they are conceived of in terms of space and time, *i.e.*, they are purely scientific facts. Psychological facts are thought of only in terms of time, and it is conceivable that this difference in mode of thinking might create an incommensurability between these two ways of thinking. This is one of the circumstances that causes difficulty.

The other circumstance consists in the fact that it is impossible to compare the complexity of our phenomena with the complexity of the psychological phenomena. It is evident that the activity of the human nervous system greatly exceeds in complexity that of the dog. Therefore psychologists are embarrassed to say to what phenomena of experimental psychology our analysis corresponds. I have received from psychologists statements that they have no parallel analysis, and I think that, owing to the indicated difficulties, for a long time we shall pursue a different road from that of the psychologists. We physiologists are not sorry for this. We are by no means placed in a difficult position. Our scheme of understanding nervous activity is simpler than that of the psychologists; we build only the foundation; they, the superstructure; and as the simple and elementary is always conceivable without the complex, whereas the complex cannot be conceived of without the elementary, our position is more favourable, for our investigations and our success do not depend in any way upon their researches. On the contrary, I believe that our investigations may be of great importance for the psychologists, as they must in the future lay a basis for psychological knowledge. Psychological knowledge and psychological investigation are very difficult; they have to do with exceedingly complicated material, and besides this they are accompanied by an extremely unfavourable condition which is absent from our work, and from which we do not suffer. Such a highly unfavourable condition of psychological research is to be seen in the fact that the investigation does not deal with a continuous and unbroken series of phenomena. Psychology has to do with conscious phenomena; and we well know that psychical life is composed in a checkered fashion of conscious and unconscious elements. The psycholo-

gist in his investigation is, it seems to me, in the situation of a man wandering in the darkness with a small lantern in his hand, which is able to illuminate only a small section of the way. You can understand that it is impossible to study the whole region with such a lantern. To every one who has been in such a situation it is well known that the view which he can obtain thus bears absolutely no likeness to that which he sees in bright sunshine. Thus we physiologists are in much more favoured circumstances. When you consider all this you will see how different are the chances of objective and of psychological investigations. Our researches are still very limited and are carried on only in a few small laboratories; indeed, one can say that they have only begun. Notwithstanding this we have a serious experimental analysis, of deep penetration and of great exactness in all its parts. If one would wish to find, however, the laws of psychical phenomena, he must admit that he is in confusion as to where to look. For how many thousands of years has man elaborated psychical facts, facts dealing with his own spiritual life? And not only do psychologists strive, but all art and all literature seek to represent the mechanics of the spiritual life of man. Millions of pages have been written to describe the internal world of the human being, but with what result? Up to the present we have no laws of the psychic life of man. Until now the proverb is true that, "The soul of another is a riddle."

Our objective investigations of the complex nervous phenomena of the higher animals fill us with a reasonable hope that the fundamental laws underlying the fearful complexity in which the internal world of man is manifested to us can be discovered by physiology, and in the not far-distant future.

CHAPTER IX

SOME GENERAL FACTS ABOUT THE CEREBRAL CENTRES

(Read before the Society of Russian Physicians, and published in *Transactions of the Society of Russian Physicians*, 1909-1910.)

THE REFLEX PATH—SENSORY (RECEPTOR) AND MOTOR (EXECUTIVE) PARTS—THE ANALYSER—PROOF THAT THE MOTOR CENTRE IS ALSO RECEPTOR.

THE brain is indeed an immense theme. By virtue of its structure and its functions it will undoubtedly attract and occupy many generations of investigators. It is too early to speak of any definite plan or functional type of brain. Consequently one should now limit oneself to the collection of facts. However, at any given time one must have a general conception about a subject, in order to have a framework on which to hang the facts, to have something on which one may build, and in order to have an hypothesis for future investigations. In scientific work such conceptions and hypotheses are indispensable.[1]

For several decades I have been occupied with the study of the nervous system; with the central nervous system especially for ten years, and with the extirpation of parts of the brain for the purpose of explaining its functions for the last five years. Thus I have collected a mass of material, and I feel the need of referring it to certain general conceptions. One of these conceptions which has formed itself in my mind, I now have the honour to present for your attention.

The basic idea in our conception of the functioning of the central nervous system is that of reflex activity in a certain nervous path along which an external stimulation, falling on the central nervous system, reaches this or that organ. This conception is, it is true, old; but, nevertheless, it is the only scientific one. It is now time, however, to pass from this primitive form of the conception to a variation of it, somewhat more elaborate. The old hypothesis, it is evident, cannot embrace all the facts which have now been gathered together. I shall endeavour in a few words to supplement the former conception.

The most important point which must be emphasised and especially

[1] It is well to call attention here to Pavlov's point of view. In his lectures he is not so much interested in publishing his results as he is in evolving his ideas in his own mind. The discussion of his experiments and schemes with others, he observes, is a great aid to him in the further development of his thoughts and plans. See also the introduction to chapter xviii. Before an audience Pavlov says he is so stimulated that he is able to criticise his own ideas better than he is ordinarily.—*Translator.*

explained concerns the central part of this nervous path. As is known, the reflex path consists of the centripetal nerve, the central apparatus, and the centrifugal nerve. We will call attention especially to the central part of the nervous path. It has been noted for many years that the central apparatus must be represented as a duplex system, *i.e.*, according to the old terminology, it consists of the sensory part and the executive or centrifugal part. It was thought that the stimulation flowing along the centripetal nerve enters the nervous system, goes into the sensory cells, and from these passes over into cells of the centrifugal nerve, and so reaches that organ in which it calls out a certain response. This duplex function of the central nervous system has not been sufficiently emphasised. In many books and articles one can read about the central nervous system, but can find no adequate explanation concerning the central part of this path, of what cells it consists, etc.; on this point, there is confusion and lack of clarity. As I reviewed my collected material, it became evident that precisely here there should be no obscurity. The matter demands that this point be brought into the light, in order that it may be clearly seen that the central section of the nervous path must always consist of these two parts. Thus, in all cases we must conceive that the stimulation first of all goes along the centripetal fibres into the cells, formerly called sensory, but better designated as receptor cells; then it passes into a connecting part, and finally into the cells of the centrifugal nerves—the efferent or executive cells. I repeat that all this is not new in the scheme of cerebral construction; it has always been mentioned, but it has never been systematically emphasised. This is the most essential point that must be kept in mind in all further investigations of the various nervous phenomena. All achievements and perfections in nervous activity are located in the receptor cells, *i.e.*, at that neglected point. All the extraordinary intricacies of function and the complicated perfections of the apparatus are evidently situated in that part of the central apparatus, and not in the centrifugal part. The latter is always simpler, more stationary, and less changeable than the centripetal.

The working centre, the effector centre, is a simple one, but the receptor centre, from which the impulse is transferred to the effector centre, is highly complicated, and in location is widely diffused. If one begins at the lower parts of the central nervous system and ascends, he will be convinced that in its construction precisely the parts of the receptory centres become more and more predominant. Into these receptor centres flow all stimulations, external as well as internal, and these centres analyse everything entering the central nervous system. Wherefore the entire reflex arc must, I think, be divided into three chief parts. The first begins in every natural peripheral end of the

centripetal nerve and ends in the receptor cells of the central organ. This part of the reflex arc I propose to consider and to designate as an *analyser;*[2] for the task of this consists directly in decomposing the entire world of stimulating influences falling on the organism from the outside, and the higher the animal, the finer is this decomposition. This is the first part. Next comes the part which must join the brain end of this analyser with the effector apparatus. This part may be called the coupling, connecting, or locking apparatus. Finally, the third part, which can be called the effector or working apparatus. Thus I represent the nervous path of the old reflex arc as a chain of three links—the *analyser,* the *connection* or lock, and the *effector* or working part of the apparatus.

From this point of view I turn to the centres of the cerebral hemispheres. I am inclined to suppose that the brain represents chiefly and probably exclusively (the last provisionally) the cerebral end of the analysers. Consequently, according to the old terminology, the cerebral hemispheres consist of the sensory centres; or, according to the terminology which I propose, the receptor centres; *i.e.,* the brain endings of the analysers. To support this there are reasons enough. That a considerable part of the hemispheres is composed of these analysers is clear; the occipital and the temporal regions are the centres for the eye and the ear. Those parts about which there is most controversy are the so-called motor regions, the frontal parts. Based on all that I have seen and considered concerning these latter areas I am inclined to the view that in their plan of construction they present no exception to that of the other parts of the hemispheres. Both contain receptor centres. This conception is not altogether my own. It originated in the year 1870 when Fritsch and Hitzig made their brilliant discovery.

During forty years this view has been upheld by many physiologists,

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[2] Under the name "analyser" Pavlov includes as a functional unity the surfaces of the body receiving the stimulation from the outer world (sense organs), the nerve or nerves conveying the impulse to the central nervous system, and the cells in the central nervous system to which this process flows. Although the important part of the physical analysis of the phenomena of the outer world belongs to peripheral structure of the analyser, the greatest physiological interest attaches to the cells of the central part of the analyser, especially in the highest parts of the brain. This part is supposed to be in close relation with the process; here the connections upon which the conditioned reflex depends are temporarily made and broken. A description of the analyser as a physiological unity will be found in the second part of the next chapter and in the first part of chapter xxi. More recent investigations show that the definition of the word analyser does not cover all the functions of this physiological apparatus; for it not only decomposes the outer world into its elementary and minute phenomena, but it also is endowed with the ability to unite several elementary phenomena into one complex stimulus, *i.e.,* it performs synthesis as well as analysis.—*Translator.*

and I myself am in favour of it. All of the formerly so-called motor region should from this standpoint be considered as a receptor centre like the occipital and the auditory areas, with this difference, that they are centres from another receptor surface, which has a special relation to movement. Therefore, it is not by chance that all physiologists agree that the region of the centres for the skin receptors and for the apparatus for movement coincides with the motor area. These several regions are entwined and entangled one with another. Certainly there are at present many contradictions in the facts. It is a subject of controversy, particularly with regard to the data of clinical observations. But I think that, discarding everything of a doubtful nature and judging strictly by the facts of physiological experiments, there will be no contradictions, if we accept the view that the motor region of the cerebral hemispheres is a place of receptor centres in exactly the same way as the occipital region is for the eye, and the temporal region for the ear.

No one has ever succeeded in producing a true paralysis by removal of the so-called motor region, as has been done by destruction of the spinal cord. In experimental animals, as the dog, no such paralysis appear; as soon as the operation is ended, even though it is very extensive, the animal, when free from the narcosis, begins to make movements in all of his extremities—all of his muscles are in activity, and not a single one is paralysed. One notices only that there is lack of order and co-ordination in the movements. In higher animals (primates) we see paralysis after such an operation; and in man paralysis is often observed clinically. But this circumstance does not dislodge me from the position which I hold. A paralysis, *i.e.*, the inability to move some member, as the hand or the foot, does not in the ape or man signify the presence of true paralysis. One must take into consideration the following: first, the higher the animal, the more complicated are its movements, and secondly, these movements do not exist pre-formed when the animal comes into the world, but must be elaborated by practice, *i.e.*, learned. Those reactions which we now call conditioned motor reflexes, are movements which are gradually formed—paths in the brain developed during the life of the individual. Consequently it is clear that the sudden loss of a large mass of external stimulations by means of which this or that movement is realised, results in the failure of the animal or man to make any special movements. We often meet the phenomenon of the apparent inability to move one or another muscle, *i.e.*, a seeming motor paralysis, which is in reality a paralysis of the analyser.

If we take a stand on the uniformity of construction of the brain, and if we closely consider our facts observed after removal of the

so-called motor region, I believe there will be no incontestable proof of the existence of true motor centres in the cerebral hemispheres.

These few considerations represent general conceptions comprising all our accumulation of facts. They will be presented in separate reports, supporting my point of view.

CHAPTER X

NATURAL SCIENCE AND THE BRAIN

(Read before the Congress of Scientists and Physicians, Moscow, December, 1909.)

SCIENCE FACED WITH THE STUDY OF ITS CREATOR, THE HUMAN BRAIN, SHOULD NOT ABANDON ITS OBJECTIVE ATTITUDE—THE BEGINNINGS OF THIS SCIENCE OF THE BRAIN—TWO MECHANISMS, THAT OF TEMPORARY CONNECTIONS AND THAT OF THE ANALYSER—UNCONDITIONED AND CONDITIONED REFLEXES—THE FOOD REFLEX AND ITS SIGNALS—CONCENTRATION ABOUT A FOCUS OF EXCITATION—THREE KINDS OF EXTERNAL INHIBITION—INTERNAL INHIBITION—THE ANALYSER, ITS ANATOMICAL PARTS AND ITS FUNCTION (ANALYSIS)—DIFFERENTIATION BASED ON INHIBITION—THE OBJECTIVE INVESTIGATION ADVANCES—THE ACTION OF THE ANIMAL IS A SERIES OF EQUILIBRATIONS WITH THE OUTER WORLD—PAVLOV'S ATTITUDE TOWARD SCIENCE AND SPIRITUAL THINGS.

ONE can truly say that the irresistible progress of natural science since the time of Galileo has made its first halt before the study of the higher parts of the brain, the organ of the most complicated relations of the animal to the external world. And it seems, and not without reason, that now is the really critical moment for natural science; for the brain, in its highest complexity—the human brain—which created and creates natural science, itself becomes the object of this science.

But let us approach the matter more closely. Already for many years the physiologist has persistently and systematically investigated, according to the strict rules of biological thought, the animal organism. He has observed the vital phenomena which appear before him in time or space, and has endeavoured by means of experiments to define the constant and elementary conditions of their existence and course. His predictions and his control of vital phenomena increase steadily, just as the control of science over inanimate nature increases. If the physiologist deals with the fundamental functions of the nervous system, with the processes of stimulation and conduction, even though these phenomena still remain obscure in their nature, he maintains his methods of natural investigation, successively studying the different external influences on this general nervous process. And even more! If the physiologist deals with the lower sections of the central nervous system, if he asks how the organism by means of this apparatus responds to this or that external condition, *i.e.*, if he studies the changes of the living substance under the influence of this or that external agent, he remains the same natural investigator. The constant reaction of the animal organism to the external world, realised with the help of the lower parts of the central nervous system, is called in physiology a

reflex. This reflex, as we might expect from the biological point of view, is strikingly specific—a certain external phenomenon calls forth a definite change in the organism.

But now the physiologist turns to the highest parts of the central nervous system, and suddenly the character of his research sharply changes. He ceases to concentrate his attention on the connection between the external phenomena and the reactions of the organism; and, instead of adhering to actual relations, he begins to make suppositions about the internal state of animals, based on his own subjective state. Up to this moment he had used general scientific conceptions. Now he changes front, and addresses himself to foreign conceptions in nowise related to his earlier ones, to psychological ideas; in short, he leaps from the measurable world to the immeasurable.[1] This is a step of extraordinary importance. What has brought it about? What deep-seated reasons have forced themselves upon the physiologist? What conflict of opinions preceded it? One is forced to give an unexpected answer to these questions. There is no precedent for this step in the history of science. The scientist, in the person of the physiologist, investigating the highest parts of the central nervous system, has unconsciously and without himself noticing it, adopted a usual and conventional habit—that of thinking of the complicated activity of animals as analogous to his own feelings and thoughts.

Thus the physiologist abandoned his strong scientific position. And what has he profited by this? He borrowed his conceptions from that body of knowledge concerning the human intellect which, as the workers in this field themselves admit, has not yet the right, in spite of its antiquity, to call itself a science. Psychology as the knowledge of the inner world of the human being is still at sea concerning its own essential methods. And the physiologist has taken over the thankless task of divining the inner world of the animal.

One can understand, therefore, why the study of the most complicated nervous activity of the higher animals has not made any remarkable progress, though it is about 100 years old. Since 1870, the work on the highest parts of the nervous system has, it seems, received an impetus to go forward; but, this has not placed the investigations on the great highway of science. Some basic facts were discovered during the first few years, and then the progress of investigation was again halted. Although the subject is a vast one, for more than 30 years the same old themes have repeatedly been worked over and there has hardly been any new conception. The objective physiologist of to-day must admit that the physiology of the brain is still uncertain. Thus, you see, psychology as an ally has not justified itself in the eyes of physiology.

[1] This idea is expanded in the last paragraph of chapter xvii.—*Translator.*

In such a state of affairs, reason demands that physiology return and proceed along the way of natural science. But what is it to do, then? In the investigation of the higher parts of the central nervous system it must remain faithful to those methods which it used in the study of the lower parts, *i.e.*, it must state exactly the changes in the external world and the corresponding changes in the animal organism, and discover the laws of these relations. But since these relations are evidently so fearfully complex, is it possible to make an objective record of them? To this essential question may be given only one serious answer—an assiduous and determined effort in that direction. And thus, purely objectively, the relation of the changes in the external world to the corresponding effects in the organism, is now being studied by many workers, using various species of animals.

I have the honour to present before your highly esteemed attention this attempt to investigate the most complicated activity of the higher animals, especially of the dog. Further I shall base my statements on the decade of work from my laboratory, in which a number of young workers have joined their efforts to mine in endeavouring to follow in this new path. This decade of effort now obscured by racking doubts, now (and more often) inspired by the feeling of assurance that our struggle would not be in vain—this work, as I am now convinced, has passed beyond this first hesitant stage and offers a certain and positive answer to the above question.

The entire activity of the highest parts of the central nervous system, as revealed to us by our point of view, stands before us in the form of two main nervous mechanisms: first, as the mechanism of a *temporary union, i.e.,* the establishment of a new connection in the conducting paths between the phenomena of the external world and the answering reactions of the animal organism; and, secondly, as a mechanism of *analysers.*

Let us consider these mechanisms separately. As I have mentioned above, physiology in the lower part of the central nervous system established years ago the mechanism of the so-called reflex, *i.e.,* the mechanism of a definite connection by means of the nervous system between certain phenomena of the external world and the corresponding definite reactions of the organism. As this is a constant and simple connection, it was natural to designate it as an *unconditioned reflex.* From our facts we concluded that in the higher parts of the central nervous system the mechanism of a temporary connection is realised. By means of this part of the nervous system the phenomena of the external world now excite the organism to activity, now fail to call forth a reaction, as if they did not exist. These temporary connections, these new reflexes, in contradistinction to the old ones, were called *conditioned reflexes.* What does the

organism profit by the mechanism of this temporary connection? When does the temporary connection, the conditioned reflex, appear?

Let us proceed from an actual example. The most essential connection between the animal organism and the environment is that brought about by certain chemical substances which must continually enter into the composition of the given organism, *i.e.*, the connection through food. In lower animal forms a direct contact between the food and the organism leads to assimilation. In the higher animals, these relations become more numerous and far reaching. Now odours, sounds and pictures attract the animal to food substances. And in the highest of all animals, the sounds of speech, and the sight of written and printed characters disperse the human race over the whole surface of the globe in search of daily bread.

In this way numberless, various and remote external agents act as *signals* for food. They direct the higher animals to seize it, impel them to realise the food connection between themselves and the external world. *Pari passu* with this variety and remoteness is the change brought about by substitution of the temporary for the constant connection between the external world and the organism; first, because the remote connections are essentially changeable and therefore temporary, and secondly, owing to their variety and number they cannot be included in even the most comprehensive scheme.

The given food object may be now in one place, now in another, it may be at one time accompanied by certain phenomena, at another time by entirely different ones and may be a part of one or another definite system of the external world. And therefore the movement reaction of the organism towards this object must be united by a temporary connection now to this, now to that external phenomenon.

In order to render more comprehensible the second thesis—that it is impossible for the remote connections to be constant—let me make a comparison. Suppose that instead of the temporary communication which is effected for us through the central telephone station, this connection became an unchangeable one, and that all subscribers became thus permanently connected one with the others. It would be expensive, awkward, and utterly impossible. Everything which is lost in this case by a certain conditionality of the connection (one cannot be connected with every subscriber every moment), is richly compensated for by the variety and number of the possible connections.

How is this temporary connection established? How is the conditioned reflex formed? For this purpose it is necessary that the new indifferent external agent coincide in time once or oftener with the influence of another agent which is already in connection with the organism, *i.e.*, with an agent which can manifest itself in some activity of the animal.

If the condition of this coincidence is fulfilled, the new agent comes into the same connection, manifests itself in the same activity as the old one. A new conditioned reflex is thus formed through the assistance of an old one. In the higher nervous system, where the process of formation of the conditioned reflexes occurs, the procedure is as follows: If a new, formerly indifferent stimulus, entering into the cerebrum, meets in the nervous system at the moment, a *focus* of strong excitation, this newly arriving stimulation begins to concentrate, and to open a road, as it were, to this focus, and through it onward to the corresponding organ, becoming in this way a stimulator of that organ. In the opposite case, *i.e.*, if no such focus of excitation exists, the new stimulation is dispersed without any marked effect in the mass of the cerebrum. Such is the formulation of the fundamental law of the highest parts of the central nervous system.

Let me now, as briefly as possible, illustrate by facts what has just been stated about the mechanism of formation of conditioned reflexes. Our entire work, up to the present, has been performed exclusively on a physiologically unimportant organ, the salivary gland. This choice, although at first accidental, proved in our further work to be a serviceable and happy one. Above all, it satisfied a fundamental demand in scientific thinking, *i.e.*, to begin with the simplest case; and, secondly, in this organ it was easy to distinguish between simple and complex forms of nervous activity, so that they could be readily separated for study. This has led to an understanding of the matter. Physiology had already known for many years that saliva begins to flow when food or some other stimulating substance is introduced into the mouth, and that this relation is established by means of certain nerves. These nerves receive the stimulations arising from the mechanical and chemical properties of the introduced substances, conduct them at first into the central nervous system and then to the gland, causing there a production of saliva. This is the old reflex, according to our terminology, the *unconditioned*—a constant nervous connection, a simple type of nervous activity which takes place in the same manner in animals from which the higher parts of the brain have been removed. And not only the physiologist, but every one knows that the salivary gland has very complex relations to the external world; for example, in a hungry animal or person the sight or even the idea of food causes a flow of saliva. According to the old terminology the salivary secretion is excited psychically. For such a complicated nervous activity the highest parts of the brain are necessary.

Our analysis concerning this point has directly shown that at the foundation of this complex nervous control of the salivary gland, this complicated relation to the external world, lies the mechanism of the temporary connection—the conditioned reflex, which I have described

before in a general way. Our experiments brought out clear and indisputable facts. Every event in the external world, every sound, picture, and odour, everything could be brought into a temporary connection with the salivary gland, could become a stimulating agent of salivary secretion, provided it coincides in time with the unconditioned reflex, with the salivary secretion provoked by the presence of substances in the mouth. In short, we can form as many and as varied conditioned reflexes on the salivary gland as we wish.

At the present time the subject of the conditioned reflex, only on the basis of the work of our laboratories, fills an extensive chapter, with a mass of facts and a number of exact rules connecting them. The following is only the most general outline, only the headlines of this chapter.

First of all, there are numerous details concerning the speed of formation of the conditioned reflex. Then follow various sorts of conditioned reflexes, and their general properties. As the conditioned reflexes are in the highest part of the central nervous system, in which there is a constant collision of innumerable influences from the external world, it is comprehensible that among the different conditioned reflexes there is an incessant struggle, a choice among them at any given moment. Consequently there are constantly arising cases of inhibition among these reflexes.

Three kinds of inhibition have now been established: *simple inhibition, extinguishing inhibition,* and *conditioned inhibition.* Altogether they form the group of *external inhibitions,*[2] for they are based on the addition of an external agent to the conditioned stimulus. On the other hand, a previously formed conditioned reflex, owing to the effect of its internal relations alone, is subjected to continual fluctuations, even to temporary complete disappearance, *i.e.,* it is inhibited internally; and this constitutes *internal inhibition.* If, for example, even a very old and strong conditioned reflex is repeated several times without being accompanied by the unconditioned reflex by help of which it was formed, it immediately begins to lose its strength, and more or less quickly, but gradually, falls to zero; *i.e.,* if the conditioned reflex as a signal of the unconditioned signalises falsely, the former immediately and steadily loses its stimulating effect.[3] This loss of effectiveness of the conditioned reflex comes

[2] At this stage of the experimental work the basis for classifying the several kinds of inhibition was the presence or absence of an external stimulus. All inhibition which was produced by external agents was put in the class of external inhibition. Further work brought about some changes in this scheme—for example, "conditioned inhibition" proved to belong to the group of internal inhibitions. For the present classification of inhibitory processes the reader may consult the first part of chapter xix.—*Translator.*

[3] The reader will remember that this process is called *extinction* of the conditioned reflex.—*Translator.*

about not by its destruction, but by its internal inhibition; for a conditioned reflex which has been extinguished in this way, after some time becomes restored *per se.* There are still other cases of internal inhibition. In further experiments a new and important side of the problem has been clarified. It has been proved that besides stimulation and inhibition of stimulation there is as often an *inhibition* of *inhibition,* in other words, "*dis-inhibition.*"[4]

It is impossible to say which of these three acts is the most important. One must simply state that all the highest nervous activity, as it manifests itself in the conditioned reflex, consists of a continual change of these three fundamental processes—*excitation, inhibition,* and *dis-inhibition.*

I pass now to the second of the above mentioned fundamental mechanisms, the mechanism of the *analyser.*

As mentioned before, the temporary connection proves to be necessary as soon as the relation of the animal to the external world becomes complex. But this great complexity of the relations presupposes the ability of the organism to decompose the external world into separate parts. And in fact every higher animal possesses manifold and delicate analysers. They are what until now have been called the sense organs. Physiological teaching about these latter, consists, as the naming of the organs themselves shows, for the most part of subjective material, *i.e.,* it springs from observations and experiments on sensations and conceptions of the human being, and thus it has been deprived of those extraordinary means and advantages of objective science afforded by animal experimentation. It is true that this region of physiology, thanks to the interest and participation of some brilliant investigators, belongs in many respects to the most elaborated branches of physiology, and contains much data of great scientific importance. But these elaborations of research concern chiefly the physical side of the phenomena in the organs, for example, they have to do with the conditions for the formation of a clear picture on the retina. In the purely physiological part, in the investigation of the conditions and kinds of irritability of the nerve endings in a given sense organ there is a mass of unsolved problems. In the psychological part, *i.e.,* in the teaching which concerns itself with the sensations and the perceptions produced by the stimulations of the organs, in spite of the accurate observations and the ingeniousness of the investigator, there have been established only elementary facts. Evidently, what the genius Helmholtz referred to as "unconscious conclusion" corresponds to the mechanism of the con-

[4] The English prefix *dis* seems to correspond best to the Russian prefix *ras* which Prof. Pavlov combines before the word for inhibition. Prof. Pavlov's term is *rastormazhivanie,* which literally translated, means *unbraking.—Translator.*

ditioned reflex. When, for example, the physiologist says that for the formation of the conception of the actual size of an object there is necessary a certain length of the image on the retina and a certain action of the internal and external muscles of the eye, he is stating the mechanism of the conditioned reflex. When a certain combination of stimuli, arising from the retina and ocular muscles, coincides several times with the tactile stimulus of a body of certain size, this combination comes to play the rôle of a *signal,* and becomes the conditioned stimulation for the real size of the object. From this hardly contestable point of view, the fundamental facts of the psychological part of physiological optics is physiologically nothing else than a series of conditioned reflexes, *i.e.,* a series of elementary facts concerning the complicated activity of the eye analyser. At present, there is here, as everywhere in physiology, much more unknown than known.

The *analyser* is a complicated nervous mechanism beginning with the external receiving apparatus and ending in the brain, now in its lower, now in its higher sections; in the last case, it is much more complex. The fact on which the physiology of the analyser is based is that every peripheral apparatus is nothing more than a special transformer of a certain given external energy into a nervous process. And there follows a long series of questions entirely undecided or only touched upon. What processes are involved in this transformation? Upon what depends the analysis? Which part of the activity of the analyser is to be attributed to the construction and process in the peripheral apparatus, and which part to the construction and process in the cerebral ending of the analyser? What consecutive phases does this analysis show, starting from its simplest, and proceeding to its highest stages? And finally, what are the general laws governing this analysis? At the present time all these questions have been put to a purely objective test in animals by means of the method of conditioned reflexes.

In establishing a temporary connection between a given phenomenon of nature and an organism, it is easy to determine in what degree the corresponding analyser of the animal is able to decompose the external world. For example, in the dog it can be shown without special difficulty that his ear analyser can differentiate the finest timbres and the separate parts of composite tones, and not only differentiate but retain this differentiation (in man called "absolute pitch"), and that his ability to distinguish high pitches is much greater than that of man; he reacts to vibrations of 70 to 80 thousand per second, whereas the limit of the human ear is not higher than 40,000-50,000.

Besides this, in the objective investigation, there appear the general rules according to which this analysis is performed. The most important of them is the gradation of analysis. It is, therefore, in the

conditioned reflex, in the temporary connection, that the given analyser takes part at first as a whole in its more general and gross activity, and only afterwards, thanks to its gradual differentiation, does its activity become more delicate and refined. For example, if a bright figure appears before the animal, then at first every reinforcement of the illumination acts as a general stimulus and only afterwards is it possible to elaborate a special conditioned stimulus from the size, form, intensity, etc., of the figure.[5]

Further, in such experiments on animals with conditioned reflexes, the fact has been brought out that differentiation comes about as a result of an inhibitory process, probably through a suppression of all other parts of the analyser except the definite part concerned. Upon the gradual development of this inhibitory process depends the gradual analysis. That this is true can be proved by many experiments. I shall give one such as a convincing example. If one breaks down the balance between the excitatory and the inhibitory processes in favour of the former, by introducing into the animal a stimulant, such as caffein, then a well elaborated differentiation is immediately and seriously damaged, and in many cases it completely disappears, although temporarily.

Objective investigation of the analysers has also manifested advantages in experiments with partial extirpation of the hemispheres. These experiments disclosed an important and exact fact; the greater the damage to the cerebral end of the given analyser, the less delicate is its work. It continues to enter into a conditioned connection as formerly, but only through its more general activity. For instance, after considerable destruction of the cerebral end of the eye analyser, one or another intensity of light can easily be made a conditioned stimulus, but definite objects, combinations of light and shadow, lose their specific stimulating effect.

In concluding the presentation of some of the facts of this new subject, I feel constrained to mention certain characteristics of the work in this field. The investigator constantly feels that he is standing on very fertile and solid ground. Questions besiege him on all sides, and his task consists in reducing them to a logical and natural order. Notwithstanding the speed of the research, its progress is sure. One who has not proved these facts himself can hardly believe how often these relations, enigmatic as they seem from the psychological point of view, are subject to a clear and successful objective physiological analysis, easily controlled at every step by suitable experiments. Again and

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[5] This process in which the power of stimulation belongs only to that single agent coinciding with the unconditioned reflex and which is lost by all the neighbouring stimuli is called *differentiation*. See footnote 4, chapter iv, and the accompanying paragraph.—*Translator.*

again the worker in this field is struck by the incredible power of objective investigation in this new domain of complex phenomena. I feel assured that every worker in this field will be seized by an extraordinary interest and passion for investigation.

Thus, on a purely objective scientific basis the laws of complex nervous activity are elaborated, and the secrets of its hidden mechanism are gradually revealed. It would be an unjustifiable pretension to assert that by the two mechanisms described above all the higher nervous activity of the higher animals is once and forever exhausted. But this is not important. The future of scientific investigation is always obscure and is replete with surprises. The essential point is that on a purely scientific basis, under the guidance of purely scientific conceptions, there is instantaneously opened up an unlimited territory for investigation.

With this conception of the complex nervous activity of the animal organism, the most general statements concerning it are thoroughly compatible. As a part of nature every animal organism represents a very complicated and closed system, the internal forces of which, at every given moment, as long as it exists as such, are in equilibrium with the external forces of its environment. The more complex the organism, the more delicate and manifold are its elements of equilibration. The analysers and the mechanisms of constant as well as of temporary connections, serve for this purpose, they establish the most precise relations between the smallest elements of the environment and the finest reactions of the animal organism. In this way then is all life, from that of the simplest to the most complex organism, including man, a long series of more and more complicated *equilibrations* with the outer world. The time will come, be it ever so distant, when mathematical analysis, based on natural science, will include in majestic formulæ all these equilibrations and, finally, itself.

When I say this, I should like to anticipate what might be misunderstood in these statements concerning my views. I do not deny psychology as a body of knowledge concerning the internal world of man. Even less am I inclined to negate anything which relates to the innermost and deepest strivings of the human spirit. Here and now I only defend and affirm the absolute and unquestionable right of natural scientific thought everywhere and until the time when and where it is able to manifest its own strength. And who knows where its possibilities will end!

In conclusion allow me to say something about the accoutrement of the investigator in this new region.

He who would venture into this new field, who would register the influences of the environment on the animal, has need of an exceptional

equipment. He must hold in his hands all the external influences. Wherefore it is necessary for this investigator to have a special and new type of laboratory: first, one in which there are no accidental sounds, no sudden light changes, no accidental air draughts, etc., where in short he may govern as far as possible the constancy of all external conditions; and secondly, one in which he has at his command a supply of the generators of many kinds of energy, capable of being varied by corresponding analysers and measuring instruments. Here must ensue a rivalry between the contemporary technic of the physical apparatus and the perfection of the animal analyser. Here will be a close alliance between physiology and physics, from which, I think, even physics will gain not a little.

Under the conditions of our present laboratories, not only is the work of which we speak often limited against our will, but it is also almost always difficult for the experimenter. For weeks he may have prepared for an experiment, and at the decisive moment, when he impatiently awaits the answer, an unexpected vibration of the building, or a noise from the street, etc., destroys his hopes, and the desired answer must be postponed for an indefinite time.

A proper laboratory for this investigation is of great scientific consequence, and it is my wish that in this country, where the foundation of such an investigation has been laid, there could be erected the first appropriate laboratory, in order that this highly important scientific undertaking should become our own and to our credit.

With a feeling of pride, I announce that my native country has answered promptly my call for a new type of laboratory. The Ledenzov Society has reacted so energetically that the Institute of Experimental Medicine has now begun the construction of such a laboratory.[6]

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[6] The work on this laboratory was interrupted by the war and revolution. During the worst year, although Prof. Pavlov's attendance was carried out with military punctuality, even when he had to walk through snow and ice, few successful experiments could be performed on account of the lack of light, fuel and food. Starving animals had to be fed to the surviving ones, which were often carried home with the investigator to share with him his meagre ration and to keep them from freezing. Pavlov alludes to these difficulties in the Preface to the first edition. After 1918 all laboratories have been supported by the State. Since 1923 increasing funds have been allocated to Pavlov's laboratories so that now they are excellently equipped and well provided for.—*Translator.*

CHAPTER XI

THE TASK AND THE ARRANGEMENT OF A LABORATORY FOR THE STUDY OF THE NORMAL ACTIVITY OF THE HIGHEST PARTS OF THE CENTRAL NERVOUS SYSTEM IN THE HIGHER ANIMALS

(Read before the Ledenzov Society for the Advancement of the Experimental Sciences and Their Practical Application, Moscow, 1910.)

THE FUNCTION OF CONDITIONED REFLEXES, THEIR RISE AND FALL—EXPERIMENTAL PRODUCTION OF SLEEP—THE SLEEP REFLEX; GENERAL INHIBITION—THE FOCUSING REFLEX—EXTINCTIVE INHIBITION—SIMPLE INHIBITION—INTERNAL INHIBITION—THE CONDITIONED INHIBITOR—DIS-INHIBITION—EXPERIMENTAL DIFFICULTIES—THE ANALYSERS—ANALYSIS; TIME AS A CONDITIONED STIMULUS—THE EAR ANALYSER—REQUISITES OF THE CONSTRUCTION AND EQUIPMENT OF A LABORATORY—GRATITUDE EXPRESSED TO THE LEDENZOV SOCIETY.

In the following short account, which is prompted by the desire to describe to you a new type of laboratory, it is impossible to present even in its most general features the entire new chapter of animal physiology, and to demonstrate the most important landmarks in the analysis of the most complicated vital phenomena. But the groups of facts with which we are concerned in this lecture testify, I think, in a high degree to the positive and exact knowledge of the animal organism derived from the laboratory investigations.

An enormous part of the external visible activity of a normal higher animal appears to me in the main as a series of countless conditioned reflexes—temporary connections between the activity of the skeletal musculature and the most diverse and minute elements of the external world upon which this activity is directed, in order to introduce food into the organism, to remove destructive influences, etc. I shall not dwell, however, on this part of the most complicated vital activity, *i.e.*, on the circumstances of formation of the conditioned reflexes and their properties, but I address myself directly to the other part of this activity. The external world perpetually calls out, on the one hand, conditioned reflexes, and on the other hand, continually suppresses them, submerges them through the action of other vital phenomena. This rising and sinking of the conditioned reflexes responds at any given moment to the demand of the fundamental law of life—*equilibration with surrounding nature.* This is adjusted and accomplished through the different kinds of inhibition of the conditioned reflexes. It is precisely these inhibitions which concern us to-day.

The constant subject of our investigation has been the conditioned

reflex, the temporary connection of various external agents with the activity of the salivary gland—an organ which is at the entrance to the digestive tract of the animal organism, and bears the same relations to the external world as skeletal muscle, but is infinitely simpler in its rôle, and in its connections with the organism. Wherefore its advantages for investigation. Various external agents, various sounds, lights and pictures, various odours and all kinds of mechanical and thermal stimuli for skin receptors—all these which were formerly indifferent towards our gland (*i.e.*, left it in a state of rest) could be transformed into temporary stimuli, into agents which cause it to elaborate its usual secretion. This is attained by uniting exactly simultaneously several times the action on the animal of one of these agents with the action of the usual physiological stimulus of the organ; such physiological stimuli are all kinds of food or various inedible substances forcibly introduced into the mouth of the dog. And now, under what external conditions or in the presence of what internal state of the animal does our conditioned stimulus lose its habitual elaborated action? The number of these conditions is certainly very great, even though they are not all known. And I shall treat only of those facts which have been established with more or less certainty.

For many years one or another of my collaborators has complained during his work with conditioned reflexes that the experimental animal became sleepy. This state rendered impossible further study of the investigated phenomena for the simple reason that they disappeared. The difficulty was especially marked when as a conditioned stimulus we used thermal irritation of the skin—either heat at 45°C. or cold at about 0°C. In the last case the experiment ended in a deep sleep and complete cessation of the complex nervous activity of the animal. There even grew up a prejudice in the laboratory against working with thermal agents. But the difficulty could only be neglected temporarily, for the matter in its very nature directly related to our problems.

As we concentrated our attention on these phenomena, we at last discovered their mechanism. Many years ago we had been surprised by the contrast between the great animation and liveliness of some of the dogs before the experiment and the drowsiness which appeared soon after the beginning of the experiment. It is clear that something during the experiment causes the sleepy state. But the experiment consisted in nothing more than feeding the dog at very short intervals with small amounts of food, or in putting weak acid into his mouth during the thermal cutaneous stimulation. As neither the food nor the acid could produce the sleepiness, the cause is to be sought only in the action of the thermal agent. As a result of different forms of experiments, it

became evident that action by one and the same degree of heat or cold on one and the same area of the skin—if these agents act for a short time but are often repeated, or better still if they act continuously for a long period—leads sooner or later to a drowsy state of the previously lively dog and even to a deep sleep. It became clear that a definite agent in the outer world may condition the state of rest of the animal and the suppression of his higher nervous activity affecting in the same sure way as other agents evoke one or another manifestation of his complex nervous function. In other words, besides the different active reflexes there is also a passive *sleep reflex.*

The outer world forces the animal at one time into all sorts of activity, necessarily connected with a destruction of the living substance, but at another time when such an activity owing to the conditions of the moment is superfluous the same external world with the same imperativeness compels the animal to rest, which insures the restoration of the living substance destroyed during activity. And only in this way does the perpetually changing physico-chemical system of the organism remain intact and preserve its identity. That sleep as an inhibition of the higher nervous activity can be conditioned, not only through the accumulation of the products of activity, but also by a particular reflex stimulus, is supported by our observations on other kinds of proved inhibitions which pass over in a truly astonishing manner into drowsiness and sleep. I believe that on this way of investigation, and not behind mountains of obstacles, lies the solution of all the unexplained mysteries of hypnotism and its related states.[1] If ordinary sleep is an inhibition of the whole activity of the higher parts of the brain, then hypnotism must be a partial inhibition only of its different departments. This episode of the sleep reflex is one of many examples met with during investigations by the objective method, *i.e.,* a method showing that it takes into consideration all the influences of the external world on the organism, no matter how minute or fleeting they may be, and that investigation by this method already partly embraces, and will finally completely embrace the activity of the organism.

The *sleep reflex* is only one kind of inhibition of conditioned reflexes. Inhibition which is induced by the sleep reflex is called by us *general inhibition,* for it inhibits also other complex nervous phenomena besides those concerned here. At every moment there is manifested in our experiments another fact of directly opposite character, *viz.,* a positive active response of the animal to every fluctuation in the environment. Every sound, be it ever so small, appearing in the midst of habitual sounds and noises which surround the dog, each weakening or reinforc-

[1] This turned out to be true. For the results of Pavlov's studies in hypnotism, see chapter xxx.—*Translator.*

ing of these constant sounds, each change in the intensity of the room illumination (the sun becoming hidden by the clouds, a sunbeam suddenly breaking through, a flickering of the electric lamp, a shadow across the window), the appearance of a new odour in the room, a warm or cold current of air, something touching the skin of the dog, as a fly or a falling speck of plaster from the ceiling—in all these and in endless like cases, there fatally begins an activity of one or another of the skeletal muscles of our animal, as of the eyelids, eyes, ears, nostrils; or the head or the trunk or some other part of the body will turn and take a new position; and these movements are either repeated and reinforced, or the animal becomes fixed in a certain pose.

We have before us again a special reaction of the organism, a reflex of the simple kind which we call an *orienting* or *focusing* reflex. If in the surroundings of the animal there appears some new agent (by this I include changes in the intensity of previously acting agents), then the corresponding receptor surfaces of the organism become focused on it, in a manner which will bring about the most favourable stimulation. This focusing is accomplished through the activity of points in the central nervous system. The stimulated points in their turn, according to the general law of *reciprocal* action of the nervous centres, as already established for the lower parts of the central nervous system, inhibit our conditioned reflex. All the current activities of the organism must give way to these extraordinary demands of the external surroundings.

In our present laboratory this is the most troublesome, the most insurmountable cause of disturbance of our basic phenomenon, the conditioned reflex. Of course, this phenomenon must itself be studied in detail, and it is being so studied; but on the other hand, it is a great impediment to the examination of the various other sides of our chief phenomenon, making it either more difficult or even impossible.

Now every new factor arising in the surroundings, if repeated at short intervals and unaccompanied by any further direct influence on the animal, becomes more and more indifferent. The orienting reflex which it calls out becomes weaker and finally disappears, and with it also disappears the inhibitory action on our conditioned reflex. Therefore, this kind of inhibition we call *extinctive inhibition*. On this extinction is based the fact that the constant composition of the surroundings remains without apparent effect on the animal. In certain kinds of experiments we intentionally apply a repetition of the stimuli which produce the extinctive inhibition in order to render these agents indifferent. But it is evident that they cannot be removed in this way altogether and forever; they are countless, and after a certain length of time, if not repeated, they are restored.

In the same class with the extinctive inhibitions must be placed the effects of many agents of the external world having a special relation to the organism, *i.e.*, definite inborn reflexes or other conditioned reflexes. All extremely strong stimuli, strong light, sudden noises, etc., provoke special reactions, as, for example, shivering or trembling of the animal, the reaction of running away, trying to break away from his stand, or the opposite cataleptic-like state; on the other hand, the sight and sound of persons having a certain relation to the experimental animal, or the sight and sound of other known animals, and various things of the same sort, condition every previously elaborated response on the part of the animal. All these reactions are certainly connected with the activity of definite parts of the central nervous system, and this activity inhibits, according to the aforementioned law, the activity which we are investigating.

The above mentioned reactions are often stronger and more constant than the simple orienting reflex, though they also lose by repetition their inhibitory action; they must therefore be regarded as a kind of extinctive inhibition. In order not to be disturbed by this sub-group of extinctive inhibitions, it is necessary as a rule to avoid them; for the gradual weakening of their effect through repetition requires much time.

But there is one more essential point; one cannot always understand the real significance of the given stimulus for the animal. Is it possible to become acquainted with all the accidental connections with the outer world which our dog has formed before he enters the laboratory? Furthermore, it is impossible to find in any reference a full enumeration of the inborn reactions of the dog. In the majority of cases there arises the question, Is the given reaction inborn or acquired?

There is in addition a number of external influences which have in greater or less degree a destructive effect on the organism. If the fixation of the animal on the stand is connected with very strong pressure on any part of the body, or if the thermal or mechanical apparatus attached to the skin damages its integrity (slight excoriation or burning), if the introduction of some irritant into the mouth causes an injury of the mucous membrane, even to a minor degree, in all these and similar cases our conditioned reflex will suffer and finally disappear entirely. Evidently any threatening destruction of the organism provokes a *defence* reaction on the part of the animal, in the form of one or another movement to get rid of the destructive agent, and, according to the general rule of the reciprocal action of the nervous centres, it inhibits our special complicated nervous activity, our conditioned salivary reflex. This kind of inhibition we call *simple inhibition,* because it arises at once as soon as the cause is present, and it remains constant, and disappears with the cause. As inhibitions of this sort may be con-

sidered certain, other internal physiological phenomena, having at a given moment a predominant importance for the organism, such as overfilling of the bladder, stimulate the nervous apparatus which controls its emptying.

The most thoroughly studied members of this group of inhibitions are the physiological factors acting upon that organ with which we are constantly concerned in our investigations, *viz.*, the salivary gland. This gland serves for the physical and chemical elaboration of food as well as for cleansing the mouth of inedible and injurious substances. The activity of the gland differs in these two cases, and is stimulated from special nervous centres under the influence of the corresponding stimuli. Between these two centres there is the same antagonism as between all others. The unconditioned reflex on inedible substances inhibits the conditioned reflex on food, and vice versa. This inhibition arises at once and also remains constant as long as the cause is effective.

As one can see from this brief review, a long series of external and internal influences are entangled with that complex nervous activity under investigation—the conditioned reflex. But in order to appreciate in its full extent the significance of the enumerated moments for this activity, it is necessary to examine in some detail other sorts of phenomena which are closely connected with the conditioned reflexes.

If the formation of a temporary connection between external phenomena and the corresponding reactions of the organism be considered an expression of the perfection of the animal machine, a manifestation of the more exact equilibration of the organism with the external world, even higher is the perfection manifested in those fluctuations to which this temporary connection is subjected through the internal mechanism of the nervous system.

If a certain agent, our conditioned stimulus, replacing and signallising food and provoking the corresponding reaction of the organism—in our case the salivary secretion—proves to be in contradiction to reality, *i.e.*, if it fails to coincide several times with eating, it gradually loses its stimulating effect. This result is brought about not through the destruction of the salivary reflex, but through its temporary inhibition by means of a special internal process. Likewise, if a conditioned stimulus coincides with the unconditioned (from which it received its stimulating effect) only during a certain moment of its presence, its stimulating action is also inhibited until this certain moment arrives. The physiological meaning of this is very simple: why should an activity take place at all, if under the given circumstances it is unnecessary? This inhibition of the temporary connection, of the conditioned reflex, we call *internal inhibition,* in contradistinction to those inhibitions which we have described as external.

We must consider a special condition in the presence of which internal inhibition occurs. If some absolutely indifferent agent coincides several times with a conditioned stimulus, when the latter happens not to be accompanied by the unconditioned reflex by means of which it had been formed, there develops an internal inhibition, *i.e.*, the given combination gradually loses its stimulating action which belonged to the conditioned stimulus alone. This additional, formerly indifferent agent, owing to which the conditioned stimulus in the combination has gradually lost its stimulating effect, we call a *conditioned inhibitory stimulus*, or an inhibiting agent, or *inhibitor*. This agent is now truly an inhibiting agent; for when joined to every other conditioned stimulus which is based on one and the same unconditioned stimulus, it inhibits it from the first test. One may suppose that the conditioned inhibiting agent is, in a certain degree, a stimulator of the process of internal inhibition, and that the entire mechanism of the conditioned inhibition is, in a certain measure, a mechanism of a negative conditioned reflex. That this is actually true is shown by our latest experiments, in which, owing to repeated temporal coincidences of the indifferent agent with the processes of internal inhibition, the indifferent agent becomes a conditioned inhibiting agent.

Internal inhibition, as appears from our work, plays an important part in the manifestation of the most complex activity of the central nervous system. It always accompanies, for example, the discriminative activity of the nervous system.

What this internal inhibition really is, remains obscure; but the obscurity does not give sufficient ground for doubting the possibilities of its detailed study. Here, as everywhere in natural science, investigation begins with the statement of the fact itself, and the systematisation of its various modifications under different conditions. This will later give us material on which may be based real conceptions of its mechanism. Thus we know at present that the process of internal inhibition is a much less stable process than that of excitation. Already we have some information about the quantitative relation between the intensities of these two processes.

This process of internal inhibition can itself be inhibited, just as the process of conditioned stimulation can. So we have inhibition of inhibition, in other words, *dis-inhibition, i.e.*, a freeing of the inhibited processes of the conditioned reflexes. As such, inhibitors of the process of internal inhibition (*dis-inhibiting agents*), appear to us all those agents which I have before described as inhibiting agents of the conditioned stimulus.

I fear that this frequent repetition and compounding of the word "inhibition," this accumulation of "inhibitions," will produce an un-

favourable impression, and will obscure the real nature of the matter. Let us clarify it by a concrete example. Take one of our conditioned stimuli, an organ tone of 1,000 vibrations per second. Thanks to its repeated coincidence with the feeding of the animal the tone produces now of itself a flow of saliva; it is a conditioned stimulus of our gland. Now I repeat it several times without accompanying it with feeding. As I have mentioned, it gradually loses its stimulating effect, and becomes indifferent for the gland. The mechanism of internal inhibition has made it ineffective, it is *internally inhibited.* At last I add to the tone which has been made thus ineffective, some new agent, for example, the flash of an electric lamp before the eyes of the dog. This stimulus has never before had any relation to the secretion of the gland. And I immediately see that the extinguished conditioned stimulus again recovers its action; saliva flows, and the dog, which during the sound of the tone, was indifferent or even turned his head away from the experimenter, now turns toward him and licks with his tongue as he is wont to do before eating. One can understand this only in the following way: the flash of the lamp inhibited, removed, the internal inhibition, and thus dis-inhibited and restored the conditioned reflex. In exactly this way occurs dis-inhibition in other cases of inhibition. Thus is conditioned inhibition dis-inhibited. It is a special case of internal inhibition.

But here there may arise some misunderstanding: if, as I have claimed, both the reflex and its inhibitors can be inhibited, what is the result of dis-inhibition, *i.e.*, what can be set free if our inhibitory stimulus inhibits the reflex itself?

A simple solution of the matter consists in the following: as I have mentioned, the process of internal inhibition is more labile (unstable) than that of stimulation; and hence there can always be found such intensities of the new external inhibitory agent as are just sufficient to inhibit internal inhibition, but not strong enough to suppress the constant, more stable process of the conditioned excitation. In this case, then, only dis-inhibition occurs. In other words there is a graduated series of inhibition intensities—an *ineffective,* a *dis-inhibiting,* and an *inhibiting.*

I cannot enter into particulars here, but allow me to testify that the study of the complex nervous phenomena at this point, with their regular changes wholly dependent on the strength of the stimuli, has produced in me some of the strongest impressions I have ever experienced in my scientific life. And I only assisted in these experiments; they were performed by one of my young and active collaborators, Dr. I. V. Zavadsky.

As all of the above-mentioned inhibiting agents of the conditioned

reflexes, at a certain degree of intensity become agents of inhibition of internal inhibition, *i.e.*, dis-inhibiting agents, their importance for the study of the complex nervous activity of the animal is doubled. In order to manage the investigation completely, in order not to be dependent every moment upon accidents, one must hold these inhibiting agents constantly under his own control.

Here one must take into account the *extinctive inhibitions;* for their presence may be accidental and entirely independent of our wishes. Notwithstanding great care in making observations, it is always difficult to locate in the mass of stimuli falling on the animal that new agent having the inhibitory effect. Without doubt the receptor processes in the animal are finer, more exact, and more extensive than they are in man; for his higher nervous activity, having to do with elaboration of the incoming nervous material, suppresses the lower nervous processes, which are concerned with the simple reception of the external stimuli.

We noted that the new unexpected agent always influenced either the conditioned reflex or its internal inhibition, and in this way diverted the course of the experiment. If only a separate isolated factor is involved, the loss is not great. You can repeat this experiment at the next time, hoping that there will be no trouble. But if you are conducting a long experiment, consisting of successive stages, the loss is considerable. A series of phenomena has to be formed in a certain order, and therefore a long period is necessary to prepare for the repetition. But this is not the worst case! Often when one has prepared weeks and months for an experiment, in the critical moment when one is awaiting the decisive fact, the result is obscured through an accidental inhibiting agent. Only the repetition of the experiment, after waiting for weeks, and with new conditioned reflexes, may rectify the matter. The nervous phenomena which we are studying are characterised by their transitoriness; every moment and with every condition they take a new turn. And therefore it may happen that the new combination under examination, which was disturbed during the first trial, does not occur in the same virgin state when the experiment is repeated after weeks of waiting. All these phenomena which we have just considered belong to one group.

Now let me ask your attention to the work of the *analysers.* These are nervous mechanisms whose duty it is to decompose the complexity of the external world into its elements, and to receive these elements as well as all their combinations. I shall illustrate by the ear analyser because it is the one on which we made the most numerous investigations. In a previous address I have mentioned that this analyser easily differentiates very delicate fractions of tones, and that the dog's range of

discrimination (70 to 80 thousand vibrations per second) is much greater than that of man.

Especially marked is the ability to discriminate between different intensities of tones. It is not difficult to make from one and the same pitch many conditioned stimuli; for example, if a small intensity of a certain tone is made a conditioned stimulus, a greater intensity of the same pitch is without the least effect. These intensities may be so slightly different that the human ear can hardly note the difference when they are repeated with a very short interval between them, or it does not discriminate between them at all, though the analyser of the dog can differentiate them when they follow one another at an interval of hours.

Unfortunately the imperfection of physical instruments sets a limit to this sort of experiment. We could not be certain, using our imperfect apparatus, whether only the strength of the tone changed or also its pitch and its quality; further, we could not control the absolute intensity of the sound. And, as I have already said, this point is of great importance for the ear analyser.

Certainly the analysis of intensity, the measuring of the strength of the external agent, is the most elementary analysis, and as we know from general physiology of the nerve, it is peculiar to the simplest element, the nerve fibre. One may suppose that in the animal the analysis of intensity lies at the basis, certainly in part, of the perception of time. The following statement may be made: whether an external agent of uniform and constant intensity acts on a given analyser of the animal, or whether the trace of an interrupted real stimulation gradually becomes obliterated in the nerve cells, every intensity of the stimulated state of the cell at any separate moment is a special element which is differentiated from all grades of intensity preceding it as well as all grades of intensity following it. Through these elements as units, time can be measured, and each separate moment of time can be signalled in the nervous system. Time itself, however, must be investigated, as we shall constantly use it in our experiments as a conditioned stimulus.

Not less delicate is the differentiation of the intervals of time, *i.e.*, the pauses between the separate sound stimuli. The ticking of the metronome (100 per minute) can be made a conditioned stimulus. After some practice the ear analyser of the dog can differentiate even after a lapse of 24 hours between a metronome beat of 104 and one of 96, *i.e.*, an interval of 1/43 of a second. The human ear cannot distinguish between these two metronomes without counting, even after the interval of one minute.

The investigation of the ear analyser of the dog has been still further

varied; differentiation was elaborated with different orders of succession of one and the same tone, and secondly, with the introduction of different long pauses between the same tone and between different tones. I shall say a few words about the first case. A conditioned stimulus was made in the dog by a series of four ascending tones. A differentiation was elaborated between this series and a series of the same tones used in descending order (of pitch). From four tones one can make, as is known, 24 permutations. An interesting question arose: how will the ear analyser react to the remaining 22 permutations of these tones? It proved that the analyser of the dog divided them into exactly two equal groups; to one, the nervous system reacted as to a stimulus, to the other, it remained indifferent; the first were referred to the group of ascending tones; the latter, to the group of descending. The examination of the tones in these permutations showed that whilst in one group the number of ascending tones was predominant, in the other, the descending tones were preponderant.

However, this is only the beginning of the study of the analyser! As a final ideal all these countless manifestations of the external world falling on the ear analyser (which are made use of by the organism in its most refined adaptations and relations to its environment) must be studied and systematised. Also the same must be done with the other analysers of the animal.

I have now finished the enumeration of facts necessary for the solution of our problem. The question arose: what means and equipment must the investigator have at hand to proceed along this new path without serious setbacks and with a chance of success? I have so chosen my facts that the answer based on these facts does not present difficulties. The first and chief condition consists in an entirely new type of laboratory. Above all, and this is by far the most essential, this building must be insulated from outside sounds, from both the street and the neighbouring rooms. And this must be carried out in spite of the many connections that are necessary between different parts of the building. I do not know how far it is technically possible, but the ideal requirement of this building or at least of some of its rooms would be complete exclusion of all extraneous sounds.* Even an approach to these ideal conditions would considerably lessen the difficulties of the investigator. The other prerequisites of this building do not represent such great obstacles. It should be uniformly illuminated. This can be done by constant and equal artificial lighting, or by changing the natural illumination so as to compensate for weather conditions and to make it correspond to the artificial lighting. Finally, there must not be any draught during the course of the experiment which brings an odour, cold, or warmth.

* Compare the famous *camera silenta* of Zwaardemaker.

Only such a building can free the mind of the investigator from the continual anxiety that some accidental and unexpected stimulus will wreck his projected experiment; only in such a building can a needless loss of time and trouble and worry be saved, and the experimenter be given the possibility of investigating his problem with exactitude.

The second demand concerns the equipment of the laboratory with exact instruments of wide variety by which it should be possible to stimulate the receptor surfaces of the animal in numerous ways. The apparatus should be capable of regulating the intensity, duration, and frequency of the conditioned stimuli, and should include electrical, mechanical and thermal agencies placed in a special room of the laboratory or in a special building in the neighbourhood of the laboratory. Other parts of the apparatus must be within the experimental room, such as different sounds, lights, pictures, odours, thermal influences, etc. In short, the experimenter must be able to reproduce before the dog the external world and its variety. This is an immense technical task which one must execute if he would work under ideal conditions. But if accomplished, it will bring its rewards in future results.

The third requisite is simple, and is easily carried out, but none the less essential. After the above conditions have been fulfilled, *i.e.*, when every slightest sound, every fluctuation of the illumination has been excluded, it is clear that for our further success provision must be made for the health and welfare of our experimental animals. Often under the present working conditions they fall into one or another kind of disease. A glaring inconsistency exists when we devote every attention to the exclusion of foreign stimuli, but disregard the state of the animal itself; for example, the dog may be suffering from some skin malady, or rheumatic pains. To our sorrow it may happen that we are forced to discard an animal having many elaborated reflexes (and their formation often demands months or years of time and work), because it has been badly housed or looked after. For the success of our experiments it is necessary to have a large, bright, warm, dry and clean building for our animals, and such does not now exist in physiological laboratories.

If the scientific rights of our new field are granted, and it seems to me that the facts already obtained sufficiently demand it, the laboratory just described is an urgent necessity for the advance of our research. This is my conviction, the conviction of one who has for many years constantly considered and thought over this matter. I was very happy and deeply grateful when my conviction, my wish, and my scientific efforts in this society to which I have the honour to speak, met with such an enthusiastic response.

A society which has already expended great sums for scientific under-

takings and their practical applications, a society which is in a favourable position for future growth on account of its material means, a society with a vital programme and with practical methods, a society whose activity is conducted by eminent representatives of both theoretical and technical branches—such a society appears to me as a factor of great importance in Russian life. The vast territory of Russia with its incalculable resources and natural strength cries out for an enthusiastic and well-supported experimental study of nature, and the application of the results of this experimental activity to the advancement of human welfare. This society must become a powerful lever in such work.

More and more there is an active faith in the power of the human mind and its special weapon—experimentation. There is a new impulse, the highest which has yet arisen, expressed in this society; it is the highest impulse underlying a general human interest (and not only a Platonic one), an impulse coursing through the whole cultured world —the interest in experimental science and its applications. Only recall the tremendous expression of this interest in America, in Stockholm, in Paris and in the Jubilee of the University of Berlin. And I believe in the future Moscow will have reason to be proud of its "Society for the Advancement of Experimental Science" and of its founder, Christopher Ledenzov, as much as it is now of its statesmen.