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REFLEXES OF THE BRAIN

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REFLEXES OF THE BRAIN[1]

§ 1. I take it that my readers have had a chance to be present at debates concerning the substance of the spirit and its dependence on the body. As a rule the debaters are a young man and an old man, if they are both naturalists, or two young men, if one of them is more preoccupied with problems of matter and the other with problems of the spirit. The argument becomes really heated when the debaters are to some degree dilettantes on the subject. In this case one is usually an expert at generalising about things which are not susceptible of generalisation at all (this being a feature of the dilettante), and the audience is treated to a performance which resembles carnival fireworks on the Petersburg Islands. Bombastic phrases, broad views and bright ideas crackle and cascade like rockets. During the debate some people in the audience—young and timid enthusiasts—feel a *cold shiver* now and then pass down their spines, some sit with bated breath, while others are covered with sweat. But at last the performance comes to an end. Columns of fire go up into the air, burst with a sparkle and die out, leaving in the mind only dim memories of lucid phantoms. Such is the usual fate of all private debates between dilettantes. They stir the imagination of the listeners for a time, but fail to convince. We get a different picture, however, when the taste for dialectical gymnastics spreads in society. In this case the debater with a reputation of a kind easily becomes an idol. His opinions become dogmas and imperceptibly creep into literature. Anyone who has followed the intellectual development in Russia during the last decade has undoubtedly witnessed such spectacles and has observed that our society is extremely fickle in these matters.

There are those who utterly dislike this trait of our society. They usually regard the fluctuations in public opinion as a chaotic fermentation of unsettled thought; they fear the uncertainty likely to accrue from the ferment; finally, in their view, the pursuit of apparitions merely distracts society from business at hand. These gentlemen are, of course, right in their way. Undoubtedly, it would be much better if society, always modest, quiet and respectable, moved directly towards attainable and useful goals without deviating from the straight path. Unfortunately, in life, as in science, almost any goal is attained by devious paths; the straight road to the goal becomes clear only when the goal has been achieved. Besides, these gentlemen forget that there have been cases when unrestrained fermentation of minds eventually led to the emergence of truths. They should recall, for example, what mankind gained from the mediaeval thought which gave rise to alchemy. It is terrible to think what would have become of mankind if the rigid mediaeval guardians of public opinion had succeeded in burning and drowning as sorcerers and evildoers all those who worked hard at imageless ideas and who were unconsciously creating chemistry and medicine. People who value truth in general, i.e., not only present, but future truth, will never ridicule any popular idea, no matter how strange this idea may seem to them.

It is with such selfless seekers of future truth in mind that I venture to communicate to society some of my ideas concerning the psychical activity of the brain, ideas which have never been expounded in the physiological literature on this subject.[2]

The matter stands thus. Human psychical activity, as we know, finds expression in external manifestations; as a rule everyone —layman and scientist, the naturalist and people studying the problems of the spirit—judge psychical activity by these external manifestations. But so far the laws governing external manifestations of psychical activity have not been thoroughly elaborated even by physiologists on whom, as we shall see later, this duty devolves. And it is these laws that I wish to discuss.

Let us, then, enter the world of phenomena engendered by the functioning of the brain. It is generally said that this world embraces the entire psychical life; few people can be found now who would not accept this idea with greater or lesser reservations. The difference in the views of the various schools consists merely in the fact that some regard the brain as the organ of the spirit, thus divorcing the latter from the former, while others declare that the spirit is the product of the functioning of the brain. Not being philosophers, we shall not discuss these differences here. We, physiologists, are satisfied that the brain is an organ of the spirit, i.e., a mechanism which, if brought into action by a certain cause, ultimately produces a series of external phenomena which are expressions of psychical activity. Everyone knows how vast the world of these phenomena is. It includes the infinite diversity of movements and sounds of which man is generally capable. But is it necessary to embrace the entire mass of these facts? Is it important not to lose sight of any of them? Of course it is, since without doing so the study of the external manifestations of psychical activity would be a mere waste of time. At first sight the task seems infeasible, but in reality it is not so, and for the following reasons.

The infinite diversity of external manifestations of cerebral activity can be reduced ultimately to a single phenomenon—muscular movement. Whether it's the child laughing at the sight of a toy, or Garibaldi smiling when persecuted for excessive love for his native land, or a girl trembling at the first thought of love, or Newton creating universal laws and inscribing them on paper—the ultimate fact in all cases is muscular movement. To help the reader reconcile himself to this thought I shall remind him of the framework which has been created by the popular mind and includes all the manifestations of cerebral activity; this framework is "*word*" and "*action*". Under "*action*" the popular mind undoubtedly visualises every external mechanical activity of man which can be accomplished exclusively with the aid of muscles, while "*word*", as the reader will readily appreciate, implies a certain combination of sounds produced in the larynx and in the mouth cavity also by means of muscular movement.

Thus, *all external manifestations of the functioning of the* *brain can be reduced to muscular movement.** Because of this, the question is simplified to a considerable degree. Indeed, milliards of diverse phenomena which seem to bear no relation to one another can be reduced to the work of a few dozen muscles (it should not be forgotten that most muscles are pairs similar in structure and action; consequently, if we know how one muscle functions we thereby know the functioning of a pair). Moreover, the reader will readily grasp that absolutely all the properties of the external manifestations of brain activity described as animation, passion, mockery, sorrow, joy, etc., are merely results of a greater or lesser contraction of definite groups of muscles, which, as everyone knows, is a purely mechanical act. Even the confirmed spiritualist cannot but agree with this. Indeed, how can it be otherwise, when we know that in the hands of the musician a soulless instrument produces sounds full of life and passion, that stone becomes animated under the hand of the sculptor? The life-giving hands of musician and sculptor perform purely mechanical movements, which, strictly speaking, can be subjected to mathematical analysis and expressed by formulas. How, then, could they express passion in sounds and images, unless the expression were a purely mechanical act? In view of this, the reader will agree that the time will come when men will be able to analyse the external manifestations of the functioning of the brain as easily as the physicist analyses now a musical chord or the phenomena of a freely falling body.

However, this happy time is still a long way off, so, instead of indulging in guess-work, let us turn to the basic question and see in what way the external manifestations of brain activity develop insofar as they express psychical activity.

Now, since the reader presumably agrees that externally this activity is always expressed in the form of muscular movement, my job is to determine the ways in which muscular movements originate in the brain.**

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* The only phenomena in this sphere which so far cannot be explained by muscular movement are the changes of the eye expressed by the words "sparkling", "languor", etc.

** Since respiratory and cardiac movements are not directly related to our subject, we shall not deal with them here.

Let us pass directly to our subject. Modern science divides all muscular movements into two groups according to their origin—*involuntary* and *voluntary*. Consequently, our task is to analyse the origin of the two groups. We shall begin with the first group—it being the simplest—and, for the sake of clarity, deal not with the brain, but with the spinal cord.

Chapter One

INVOLUNTARY MOVEMENTS

Three types of involuntary movements.—1) Reflexes (in the narrow sense) in decapitated animals; the movements of man in sleep and when his brain is, so to speak, inactive.—2) Involuntary movements in which the end of the action is to a greater or lesser degree weakened compared with the onset (inhibited involuntary movements).—3) Involuntary movements with an intensified end—fright, elementary sensual enjoyment. —Cases in which the interference of the psychical factor with the reflex does not change the nature of the latter.—Somnambulism, alcoholic intoxication, delirium, etc.

§2. Pure reflexes, or reflex movements can be best observed on decapitated animals, especially on the frog, since in the latter the spinal cord, nerves and muscles continue to function long after decapitation. Cut off the head of a frog and place the decapitated animal on the table. For a few seconds it seems to be completely paralysed; but before a minute has passed you see that it has recovered and assumed the posture peculiar to the frog when in a state of rest on dry land: its hind legs are tucked under it and it supports itself on the front legs like a dog. If you leave it alone, or to be more precise, if you do not touch its skin, it will remain motionless for a very long time. But the moment you touch its skin, it starts and then resumes its quiet posture. Pinch it somewhat stronger and it will, in all likelihood, jump as if trying to escape from the pain.*

* Actually a decapitated animal does not feel pain as a conscious sensation in those parts of its body which have been separated from the head. This has been proved by observations of people the upper part of whose spinal cord has been destroyed to a greater or lesser extent; in this case the skin of the lower half of the body is rendered completely insensitive.

But when the pain passes it will sit without movement for hours. The mechanism of these phenomena is extremely simple: sensory nerve fibres stretch from the skin to the spinal cord, while from the latter motor nerves extend to the muscles; in the spinal cord itself the two kinds of nerves are connected by means of the so-called nerve-cells. Intactness of all the parts of this mechanism is indispensable for the accomplishment of the above-mentioned phenomenon. Indeed, if you transect the sensory or the motor nerve, or if you destroy the spinal cord, stimulation of the skin will not produce any movement whatever. Such movements are called *reflex*—because here excitation of the sensory nerve is reflected in the motor nerve. Further, it is clear that these movements are involuntary—being caused only by obvious stimulation of sensory nerves. But when this stimulation takes place, the movements are as inevitable as the fall of a body left without support, or the explosion of powder when it comes into contact with fire, or the work of a machine which has been set in motion. Consequently, these movements are mechanical in their origin.

Excitation of the sensory nerves, excitation of the spinal centre linking the sensory nerves with the motor nerves, and excitation of the latter, expressed in contraction of muscles, i.e., in muscular movement—such are the acts that comprise reflexes or reflex movements.

The reader should not, however, conclude that reflex movements are inherent only in decapitated animals; on the contrary they exist when the brain is intact, both in the sphere of the cranial nerves and in the sphere of the spinal nerves. To come under the category of reflex movements it is only necessary that the movement should clearly result from stimulation of a sensory nerve and be of an involuntary nature. Such at any rate is the point made by the present-day school of physiology.

In this sense, for instance, an involuntary start caused by a sudden sound, by an unexpected touch on the body, or by the abrupt emergence of a certain image before our eyes, can be described as a reflex movement. And it should be clear to everyone that when the brain is intact the sphere of reflex movements is immeasurably wider than in a decapitated animal; the reason is that in the decapitated animal of all the sensory nerves the excitation of which produces reflex movements only the cutaneous nerves remain intact, whereas the normal animal possesses, along with cutaneous nerves, optic, auditory, olfactory and taste nerves. In any case the reader can see that all so-called reflex, involuntary, mechanical movements exist not only in decapitated animals, but in the normal man as well. Consequently, the brain, or the organ of the spirit can, in certain conditions (according to this school), produce movements as inevitably as any machine, just as, for example, the hands of a clock inevitably move when the clock wheels are turned by the weights.

This idea of the mechanical nature of the brain, irrespective of these or other conditions, is a real find for the naturalist. He has seen many diverse and intricate machines—from a simple screw to complex mechanisms which to an ever-increasing degree replace manual labour; he has meditated so much on these machines that, if you confront him with a new machine without letting him see its interior but showing him only the beginning and the end of its work, he will form a more or less correct idea both of the design of the machine and of its operation. But though we have the good fortune to belong to this category of naturalists, we shall not rely too much on our powers when we come to examine the brain, because the brain is the most intricate of all machines. We must be modest and cautious in our deductions.

We have found that the spinal cord in the absence of the brain *always*, i.e., *inevitably*, produces movements when a sensory nerve is subjected to stimulation; this circumstance is regarded by us as the first sign of the mechanical nature of the functioning of the spinal cord in accomplishing movements. Further study of this question has shown, however, that the brain, too, may under definite conditions (*but not always*) act like a machine, its functioning being manifested in so-called involuntary movements. In view of these results, it is only natural that we should try to determine the conditions under which the brain acts like a machine. As mentioned above, any machine, no matter how intricate, can be subjected to investigation. Consequently, strict analysis of the conditions under which the brain acts as a machine will give us a clue to an understanding of the brain. Let us, then, begin.

§3. Everyone knows that involuntary movements originating in the brain arise only when a sensory nerve is subjected to unexpected stimulation. This is the first condition. Now let us see whether there are other conditions; for the sake of clarity we shall resort to examples. You are in the company, say, of a nervous lady. You warn her that you are going to bang the table, and then proceed to do so. In this case the sound acts on the auditory nerve of the lady not suddenly or unexpectedly; nevertheless, the lady starts. From this fact you can easily draw the conclusion that sudden stimulation of the sensory nerve is not an indispensable condition for the emergence of an involuntary movement, or that a nervous woman is an abnormal, pathological person in whom phenomena develop reversely. However, refrain for a moment from drawing conclusions and go on with your experiment. With the lady's permission you continue to knock on the table with the same force, bringing the number of knocks to several per minute. Ultimately a stage will be reached when the knocks no longer affect the lady: she will not start any more. This is usually explained either by the adaptation of the sensory organ to the stimulus, or by a decline in its sensibility, i.e., by fatigue. We shall return to this explanation later; now let us continue the experiment. When the lady has got used to knocks of a certain strength, you add to the strength warning the lady beforehand. She will start again. When knocks of the same strength are repeated, the reflex movements disappear again. Any subsequent increase in the strength of the knocks results in their reappearance, and so on. It is obvious that for every person in the world there is a sound which is strong enough to make him start even if the sound is anticipated. The only condition is that the stimulation of the auditory nerve should exceed in strength all stimulations ever experienced before. Any veteran of Sevastopol, for example, who by force of habit calmly endured the cannonade of a thousand guns would undoubtedly start if a million guns opened fire. I shall not cite similar examples relating to the sphere of other sense organs, since now the reader himself can easily imagine the effects of gradually intensified excitation of the optic, olfactory and taste nerves. In all cases he will come, of course, to the same conclusion: *if excitation of the sensory nerve is stronger than those previously experienced, it will in all conditions inevitably evoke reflex*, i.e., involuntary movements. This is the second and last category of cases where the brain acts like a machine in producing movements. In all other cases muscular movements effected under the influence of the brain are described by physiologists as voluntary. We shall discuss these movements below, in the meantime we shall revert to the conditions under which involuntary movements arise and shall try to express them in the language of physiology.

If we examine these conditions more closely, we shall easily establish their similarity. Indeed, in the first case it was the absolute suddenness of the sensory stimulation which produced the reflex movement, in the second it was merely the relative suddenness. Whereas in the first case the strength of stimulation increased, so to speak, instantaneously from zero level, in the second it merely exceeded that which was already familiar to the sensory organ and which was expected by it. However, notwithstanding the seeming resemblance, there is an essential difference between these conditions; the difference can be best illustrated by an example. A man standing in the centre of the room is wholly unaware of what is taking place behind him. If pushed slightly in the back he jumps a little from the point where he stood. The picture will be quite different if the man expects the push; in this case he so adjusts his muscles that even a stronger push will not move him from his place. It is clear, however, that in this case too he will not be able to retain his position should the push be much stronger than he expected. This example shows that there is a tremendous difference between the state of a person when an external influence affects him suddenly and the state when he is prepared for this influence. In the latter case, the person offers active and purposeful resistance to the external influence; in our example it is expressed by the so-called voluntary contraction of a definite group of muscles. Nevertheless, I shall try to prove that this active counteraction on the part of the person manifests itself *invariably* when he is keyed to meet a certain external influence.

It is easy to see that this is an *extremely frequent* occurrence. Let us recall the nervous lady who could not resist a light noise, even an expected one. In the expression of her face and in her entire pose there is something which we usually designate as determination. This, of course, is the external, muscular manifestation of the act by which she tries, though vainly, to overcome the involuntary movement. You can easily observe this manifestation of will (though it is not sufficiently pronounced to be described in words), having seen similar manifestations a thousand times. For example, you often see in pictures men whose appearance and pose distinctly tell you that they are threatened by certain external influences and are keyed to resist them. The face and the pose of such a figure enable you to judge of the degree of counteraction as well as the degree of danger. Thus, counteraction appears quite frequently if an external influence is expected. But how are we to explain the following facts: a person is prepared for the external influence, and the latter does not evoke any involuntary movements; moreover, confronted with the hostile influence he remains absolutely calm, i.e., his appearance does not betray even a trace of the above-mentioned counteraction. You, for example, are not a nervous person and know that someone intends to frighten you with a knock which makes only nervous ladies start. Naturally, you will remain calm both before and after the knock. Your friend, for example, takes cold showers and is able to refrain without difficulty from involuntary movements if he uses water with a temperature of 8°C. A third person is used to the smell of the dissection-room, and, naturally, he will not feel any strain or make a wry face when entering a hospital ward. Is the above-mentioned counteraction to external influences present in these cases? Of course, it is; the reader can gauge this by very simple reasoning. For the sake of clarity, let us again take the example of the nervous lady who is frightened by knocks. We have seen that when the knocks are repeated with the same force, she finally ceases to start. Watch her facial expression and her pose during the experiments. You will see a look of grim determination, though the lady is still unable to overcome her fright; later, the same determination is sufficient to resist stronger sounds; finally, the moment comes when she endures the knocks without her pose of grim and resolute determination. This phenomenon is, apparently, best explained by fatigue of the auditory nerve; this, though partly true, does not explain the matter fully. Indeed, if you test the lady's hearing at the time when the loud knocks no longer act upon her, you will find that it has not dulled to any appreciable degree even to the weakest sounds. Consequently, there is another cause, commonly known as habit. In the given case the habit consists in the fact that in the course of the experiments the lady develops resistance to the knocks. Another example will show that this interpretation of habit is not arbitrary. Anyone who has observed a person beginning to study the piano is aware of the strain he undergoes when he learns to play the scales. The poor beginner not only acts with his fingers; he also moves his head, mouth and the entire body. But look at the same person when he has developed into an artist. He runs his fingers over the keys with absolute ease; the movements are so rapid that they seem to be independent of the musician's will. Meanwhile, here, too, it is a matter of habit. In this case habit conceals from your eyes the efforts exerted by the musician when moving each finger separately, just as in the case with the nervous lady habit disguises her efforts to counteract the knock. So as not to overburden the subject with further examples, I shall ask the reader: Is there anything in the world so loathsome or so horrible that a human being could not become accustomed to it? Everyone will undoubtedly answer that no such thing exists; and yet it is common knowledge that the process of getting accustomed to many things requires protracted and strenuous effort. To become accustomed to something horrible or disgusting does not mean to endure it without any effort (this would be obvious nonsense); it means skilfully to control such effort.

Thus, if a person is keyed to meet an external influence, he *invariably* exhibits resistance to it, irrespective of the ultimate effect (i.e., no matter whether there is an involuntary reflex movement or not); at times this resistance is expressed externally in a muscular movement, sometimes it remains without any perceptible external manifestation.

We are now in a position to clearly differentiate between the two sets of conditions indispensable for the emergence of involuntary movements when the brain is intact. When the impression is absolutely unexpected the reflex movement is effected exclusively through the nervous centre connecting the sensory and the motor nerves. But if the stimulation is expected, a new mechanism interferes with the phenomenon seeking to suppress and inhibit the reflex movement. In some cases this mechanism suppresses the power of stimulation, and then no reflex (involuntary) movement takes place. In others, on the contrary, the stimulation overpowers the obstacle and then the involuntary movement appears.

This, of course, is the simplest and easiest explanation; but it requires a physiological foundation, since it is a question of the existence of new mechanisms in the brain whose action can, apparently, be observed also in animals. We shall, therefore, turn to the question whether there are physiological grounds for admitting the existence in the human brain of mechanisms that inhibit reflex movements.

§4. About twenty years ago physiologists still believed that excitation in a nerve terminating in a muscle invariably causes the muscle to contract. But quite unexpectedly *Eduard Weber*[3] demonstrated by direct experiments that excitation of the vagus nerve, the branches of which lead also to the heart, far from intensifying the activity of this organ, on the contrary, paralyses it. Weber's contemporaries were at first greatly surprised at this discovery and then decided (in any case, most of the physiologists of the day) that this abnormal action was due to the fact that the nerve does not end directly in the muscle fibres of the heart, as in the muscles of the body, but in the nervous ganglia dispersed in the tissue of the walls of the heart. Ten years after *Weber*'s discovery *Pflüger*[4] established that *n. splanchnicorum* exerts a similar influence on the small intestine. Here, in the muscular walls, were found the same nervous ganglia as in the heart. Later, *Claude Bernard*[5] expressed the idea that *chorda tympani*, stimulation of which manifestly increases the secretion of saliva, should be regarded not only as a stimulus, but also as an inhibitor (or regulator) of salivation. Finally, *Rosenthal*[6] proved that respiratory movements, essentially involuntary, cease or become retarded when the fibres of the superior laryngeal nerve are stimulated. These facts gradually led modern physiologists to the belief that there may be nervous influences in the animal body which lead to suppression of involuntary movements. On the other hand, everyday life offers a multitude of examples when human will appears to act just in the same way: we are able, for example, to stop at will our respiratory movements in any phase of their development even after expiration when the respiratory muscles are relaxed; man can also suppress screams and any other movements caused by pain, fright, etc. It is remarkable that in the latter cases, which presuppose the presence of considerable moral power in the given person, the effort of will aimed at suppressing involuntary movements externally find little or no expression at all in accessory movements; the person who remains absolutely calm and motionless in these conditions is regarded as possessing strong will power.

In the face of these facts contemporary physiologists could not but admit the existence in the human body—namely, in the brain through which man's will acts—of mechanisms which inhibit reflex movements.

This hypothesis turned into an almost indubitable truth when at the end of 1862 it was proved by direct experiments that in the brain of the frog there are mechanisms which, when subjected to stimulation, suppress painful reflexes from the skin.

Thus there can be no doubt that any resistance to sensory stimulation is caused by mechanisms that inhibit reflex movements.

This settles the question of the origin of involuntary movements arising in the brain. In both cases (that is, when stimulation of the sensory nerves is absolutely or relatively unexpected) the mechanism of the origin of reflex (involuntary) movements must be essentially the same, differing in no way from the mechanism which exists in the spinal cord. The best proof of this can be had by comparing the apparatus which produce involuntary movements in the decapitated and in the normal animal, and which have been thoroughly studied in the frog. In the decapitated animal the reflex apparatus for each point of the skin consists of the cutaneous nerve *a* (Fig. 1) entering the spinal cord and ending in cell *b* of the posterior horns; this cell is connected with another cell *c*, situated in the anterior half of the spinal cord and, together with cell *b* forms the so-called reflex centre; the motor fibre *d* issues from cell *c* and ends in the muscle. The reflex, being the product of the functioning of this apparatus, is none other than continuous excitation of *a*, *b*, *c*, and *d*, always beginning with the stimulation of *a* in the skin. As to the reflexes of the brain, they are effected by a mechanism consisting of the following parts: cutaneous fibre o terminating in the nervous centres *N* which produce the walking movements (as shown by Berezin,[7] there is a difference between cutaneous fibres ending in the brain and in the spinal cord); path *Nc* along which the voluntary motor impulses proceed from the brain; and, finally, components c and *d* which enter the spinal mechanism. This apparatus is also brought into action by excitation of o, i.e., of the cutaneous nerve. Both reflexes are, apparently, identical as to their origin so long as the excitation follows the above-mentioned path; they remain identical even when the inhibitory apparatus *P* comes into action, since this apparatus is effective for *N* as well as for *bc* and is located in the brain, in front of *N*. Those who hold that the resistance to external influences is voluntary, must, of course, admit that the will acts directly on *P*; later, however, we shall see that the inhibitory mechanisms

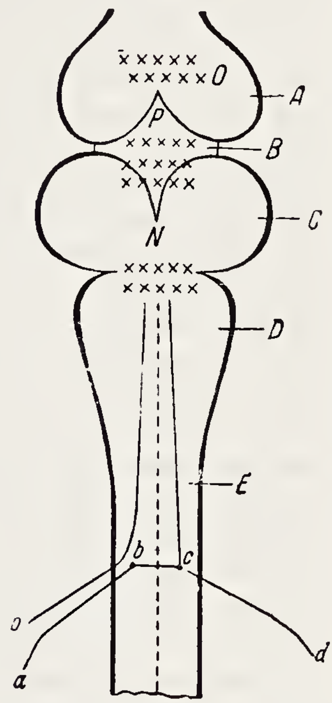

Fig. I illustrating the spinal cord and the brain of the frog
A—hemispheres; *B*—visual chambers; *C*—corpora quadrigemina; *D*—medulla oblongata; *E*—spinal cord

can be excited also by stimulating the sensory nerves of the skin.

§5. Now let us continue with our study of the brain as a machine, and establish the relationship between the intensity of stimulation and the reflex movement, that is, between the stimulus and its effect. In doing so we shall again take the phenomena presented by the spinal cord, since they have been thoroughly investigated. Here it can be said in a general way that with intensified stimulation the tension of the movement gradually grows and extends simultaneously to an ever-increasing number of muscles. For example, a slight stimulation of the skin of the hind leg in a decapitated frog results in the contraction of the muscles of this leg only. If the stimulation is gradually intensified, reflex movements appear also in the foreleg of the same side, and finally in the hind and forelegs of the opposite side.

The same can be observed in the cranial nerves when the brain, so to speak, is inactive.

For example, if the face of a sleeping person is slightly brushed (where the trigeminal nerve divides) with a feather, only the facial muscles will contract. If the irritation is intensified, reflex movements will appear also in the hand and, given very strong irritation, the man will wake up and jump out of bed, i.e., reflexes will be manifested in practically all the muscles of the body. This shows that with the intensification of the stimulus the reflex movement becomes more pronounced and simultaneously more widespread.

It is a different matter altogether when the brain is active. In this case the relationship between intensity of the stimulation and its effect is much more complex. As far as I know, this matter has as yet not been scientifically investigated; in view of this, I deem it necessary to dwell on it in more detail.

Let us analyse cases of absolutely unexpected stimulation of the sensory nerves in animals and man when the brain is intact. Suspend a frog by its snout vertically and wait until it has ceased to struggle and is motionless; then lightly touch its hind leg with your finger. The frog will display what is usually called "fright": it will begin to struggle again, i.e., bring all its muscles into action. It is commonly said that bears subjected to sudden fright (i.e., when the sensory nerves are subjected to unexpected stimulation) begin to run as fast as they can, sometimes even exhibiting a bloody flux. Thus, the fact that exceptionally pronounced involuntary movements are observed in animals as a result of slight sudden stimulation of the sensory nerves is well known. In man this phenomenon is even more pronounced, especially in the case of a hysterical woman: a sudden knock or unexpected touch to the skin may induce convulsions of the whole body (i.e., reflex movements).

But apart from this extreme case, everybody knows that sudden fright, no matter how insignificant the cause (i.e., stimulation of the sensory nerve), always evokes in man pronounced and extensive reflex movements. It is also well known that fright may result from stimulation both of the spinal and cranial nerves. Indeed, we experience fright at the unexpected touch to our trunk (which is innervated by the spinal nerves) as easily as we do at the unexpected emergence of a strange image before our eyes, i.e., excitation of the optic nerve issuing from the brain.

In any case there is no doubt that fright deranges the relationship between the intensity of stimulation and its effect (i.e., movement), in favour of the latter. Can we, then, assume that the involuntary movement occasioned by fright is of a mechanical nature? In this case a psychical element, namely, the sensation of fright, interferes with the phenomena; the reader will have heard of the miracles wrought by people under the influence of fright: for example, persons suffering from short breath run for miles without stopping, feeble individuals carry heavy loads, etc. True, in such cases the unusual energy of the muscular movements is generally attributed to the moral effect of fright; however, nobody will, of course, believe that this really explains the matter. Let us see whether it is possible to imagine a machine where the impulse to action is slight while the effect of the action is very great. Given a machine of this kind there would be no grounds for denying the mechanical nature of the origin of the involuntary movement caused by fright. Here is an example. Electric wires leading from a powerful galvanic battery are coiled round a horseshoe-shaped piece of soft iron. Placed underneath at either end at a distance is a lump of iron weighing about ten poods. The circuit is opened and the machine is motionless. At the point where the circuit is interrupted one lead is submerged in mercury, while the other reaches almost to the surface of the mercury, but without touching it. It suffices to blow on the second lead for it to dip into the mercury. The circuit will then be closed; the horseshoe becomes a magnet and attracts the lump of iron. Thus, the impulse (the blowing) is weak, while the effect (the raising of the iron) is quite considerable. The same thing is observed when a spark comes into contact with gunpowder. True, the spark itself constitutes a certain force (it can be approximately measured provided the incandescent substance and its temperature are known); but it is nil compared with the force of the exploding gunpowder.

Consequently, it is not only possible, but even necessary to reconcile the fact of the machine-like nature of the origin of involuntary movement caused by fright with the disparity between strength of stimulation and intensity of movement observed in these cases; otherwise we should fall into an absurdity inexcusable even for a spiritualist, since we should have to admit that purely material (muscular) forces are engendered by moral forces.

But in connection with the foregoing the reader is entitled to demand that we reveal in the human brain a mechanism that would explain the phenomena of fright.

This is precisely what we are going to do.

The scheme of the mechanism is as follows: fright is equally inherent in man and in the simplest animal organisms which, according to our belief, are governed by instinct alone. Fright, therefore, is an instinctive phenomenon. This sensation originates in the brain, being the inevitable result of sudden stimulation of a sensory nerve just as a reflex movement is the inevitable consequence of fright. Such are the three, causally interconnected activities of one and the same mechanism. Stimulation of the sensory nerve constitutes the onset of the phenomenon, the sensation of fright—its continuation, and the intensified reflex movement—its end.

Let us take a case when fright follows from stimulation of a spinal nerve.

Here excitation proceeds to the brain (since conscious sensations[8] originate in this organ alone), namely, to its anterior parts —the so-called cerebral hemispheres; when the latter are removed the animal no longer experiences fright.* Consequently, the processes which intensify the final effect of a reflex compared with its beginning take place in the cerebral hemispheres. This can be explained in two ways: either the mechanism which intensifies the final effect of the reflex is in its structure a reflex apparatus itself, and therefore acts simultaneously as the end of sensory nerves and the beginning of motor nerves; or it is an appendage to the reflex apparatus *N* (Fig. 1) already known to the reader, the apparatus which in the frog is situated far behind the hemispheres and produces brain reflexes. The second assumption is much more probable than the first, since all the points of the skin without exception are reflexly connected with the striated skeletal muscles through the midbrain, i.e., independently of the cerebral hemispheres. Moreover, direct experiments have shown that of all the parts of the brain the hemispheres alone do not produce muscular movements when subjected to artificial stimulation; in other words, they do not contain any fibres with properties similar to those of the motor fibres.

Thus, it appears that the brain mechanism producing involuntary (reflex) movements of the trunk and extremities possesses two appendages also situated in the brain; one suppresses movements, while the other, on the contrary, intensifies them, depending on the strength of the stimulus. In all probability the second appendage is brought into action exclusively by stimulation of the sensory nerves and, together with the reflex apparatus, *N*, constitutes the mechanism of fright. From this point of view, it can be admitted, for the sake of simplicity, that the sensation of fright and excitation of the apparatus which intensifies the final effect of a brain reflex are identical. In any case, a close causal relationship between them is beyond any doubt.

* In this case the animal becomes, as it were, drowsy; though it is still able to respond to stimulation of the skin, the movements are of an automatic nature, sharply distinguishing them from the movements of a normal animal.

The scheme which explains the mechanism of fright as being the result of sudden stimulation of spinal sensory fibres can be applied without the slightest modifications also to stimulation of the cerebral nerves, for example, of the optic, auditory and other nerves.

Thus, the reader is now confronted with a case where a psychical phenomenon becomes part of a chain of machine-like processes. The approach which has been developed here is probably new to him; perhaps the analogy of the magnet and the mechanism of fright does not satisfy him and he still doubts.

I shall repeat once more: if a man is subjected to the action of an external agent and is not frightened by it, then the intensity of the ensuing reaction (whatever muscular movement it may be) will conform to the intensity of the external influence. But when the latter produces fright the man's reaction assumes a violent character. What I assert is that in the latter case the activity of the new mechanism intensifying the reaction is added to the activity of the old mechanism which produces the reaction. It makes sense, doesn't it? But do we know of any laboratory experiments with a machine capable of intensifying reflexes similar to the experiments already carried out with mechanisms which inhibit them? Yes, experiments of this kind have been carried out,* and I shall gladly describe them here—they are simple, clear and should convince anyone who approaches the given question without prejudice. G. Berezin,[9] assistant in the physiological laboratory of the Petersburg Academy, has found that if a frog is kept in room temperature (i.e., at 17-18°C) for several hours and if its hind legs are then immersed in ice-cold water, it will immediately withdraw them. The frog feels the cold which gives an unpleasant sensation and makes a definite movement in order to get away from it. It should be pointed out that the movement is always a pronounced one—as if the frog were frightened. But if the immersion in ice-cold water is repeated after the hemispheres have been removed, the frog remains absolutely quiet. The effect is different, however, when the skin surface subjected to cooling is

* In 1863, when the first edition of *Reflexes of the Brain* appeared, none of the experiments described below had as yet been performed.

increased, i.e., if, for example, the entire posterior half of the body is immersed in ice-cold water: the frog will then move its legs. Is it not obvious that in producing movements by cooling the skin the cerebral hemispheres act in the same way as the extension of the cooled skin surface? Anyone knows that the latter condition intensifies the effect of cooling in general (the sensation of cold becomes unbearable): consequently, *the hemispheres, too, intensify the effect of cooling, i.e., the movements.* Another experiment proving the existence in the frog's brain of mechanisms which intensify involuntary movements was carried out by *Pashutin*[10], a student. He found that the movements of a frog in response to a touch to its skin are greatly intensified when its mid-brain is stimulated by electric current. In this case, the frog acts in exactly the same way as a man who is touched unexpectedly: it starts, bringing its muscles into play. But when its brain is not subjected to stimulation, it often remains motionless when touched.

Leaving aside these direct experiments, the idea of the existence in the body of mechanisms which intensify involuntary movements is corroborated by similar phenomena taking place in respiratory and cardiac activity. Each of the nervous mechanisms controlling the respiratory movements or the heart beating is supplied with two antagonistic nervous regulators: one suppresses respiration and heart beating up to complete stoppage, the other, on the contrary, intensifies them.

Do we need any other proofs that the mechanism of involuntary movements which we are considering here also possesses two antagonistic regulators—one suppressing movements and the other intensifying them.

I will conclude this part by saying a few words about two consequences which can be brought on by extreme fright: fainting, and the state which is figuratively called "petrifaction". Both phenomena, despite their ostensible dissimilarity, belong to the category of intensified reflex movements. Indeed, fainting occurs as a result of a reflex from a sensory nerve on the vagus nerve; the latter, when greatly excited, weakens the contractions of the heart to a considerable degree, or even stops them completely for a time. As a result, the supply of blood to the brain ceases (paleness of the face), leading to loss of consciousness. Fainting is usually preceded by a state of depression of the muscular and nervous systems known as fright paralysis. This explanation is in no way far-fetched. I take it that everybody knows that at the moment of fright the heart stops and only subsequently begins to beat strongly. As to people petrified by fright I have seen them only in pictures, where this state is usually expressed by an intensified and protracted contraction of the facial muscles, as well as of some of the body muscles (stupor). Consequently, here too the effect of fright is an intensified reflex movement.

I shall not dwell on cases of fright connected with anticipated sensory stimulation. The reader will be aware that in this case the disparity between the strength of the stimulus and the intensity of the resulting movement is greater than in the case just described; this is due to the fact that here, along with mechanisms intensifying the reflex movements, mechanisms come into play which inhibit them. It is likewise clear that our presentation of this process, based on analysis of absolutely unexpected stimulations and of their effects, remains valid also in those cases when the stimulation is not unexpected.

§6. Numerous reflex movements, where sensual enjoyment in the broad sense of the term constitutes the psychical element, should also be included in the category of involuntary movements, being due to the predominant activity of the reflex-intensifying mechanism. To avoid misunderstanding, I shall illustrate by examples what kind of phenomena I have in mind. They are: the laugh of a child at the sight of a brightly-coloured object; the muscular contractions which impart a characteristic expression to the face of a hungry man when he eats, or to the face of an amateur of delicate perfumes when he smells his favourite aroma, etc. In a word, they include all the muscular movements deriving from elementary sensual pleasures.

Naturally the development of these phenomena is the same as in the case of any involuntary movement in general: excitation of the sensory nerves constitutes the beginning, the activity of the centre (or enjoyment) its continuation, and muscular contraction the end. But the conditions under which reflexes of this kind arise are quite different.

Everybody knows that one and the same external influence acting on one and the same sensory nerves can in some cases engender pleasure, in others—not. For example, when a man is hungry he enjoys the smell of food; when sated he is indifferent to it and, if overfed, he even has an aversion for it. Take another example. When a man who lives in a dimly lit room enters a brightly lit room he experiences pleasure; when he returns to his own room the reflex is reversed. But let our man spend some time in a dark cellar and he will return to his room with an expression of happiness on his face. The same is true for any sensations yielding positive or negative satisfaction, that is, in all spheres of the senses. What, then, is the cause of these phenomena and can it be expressed in physiological language? First of all, is it possible to grant the existence of special mechanisms for every change in sensation? Of course not, since in our example with the influence of the smell of food on a hungry man and on a sated person we should have to accept in this case alone the existence of at least three separate mechanisms, namely, for pleasure, indifference and aversion. We should likewise have to accept the existence of such mechanisms for all the smells in the world. But it is much simpler to assume that the nature of sensation is modified by the changes taking place in the physiological state of the nervous centre.[11]

This change can even be presented—hypothetically, of course—in a mechanical form. Suppose, for example, that the central part of the mechanism, which begins in the nose with the olfactory nerves perceiving the smell of food, is at a given moment in a state that the reflexes from these nerves proceed predominantly to the muscles producing laughter; then, naturally, excitation of the olfactory nerves will make the person smile. If, on the contrary, the centre is in such a state that the reflexes develop only in the muscles which pull the corners of the mouth down, then the smell of food will result in a wry face. Now it only remains for us to admit that the first state of the centre conforms to the case when a person is hungry, the other to the case when he is sated, and the whole matter becomes clear.

Thus, it is quite reasonable to admit that involuntary movements resulting from sensual pleasure are simply ordinary reflexes, whose greater or lesser complexity, i.e., greater or lesser degree of development, depends on the physiological state of the nervous centre.

But the reader may ask: Why are these phenomena included in the category of the reflex movements engendered by the activity of an element intensifying reflexes? In the past the generally accepted view was that besides excitatory effects there were also inhibitory effects, and that, for example, all kinds of aversion belong to the latter. To answer this question, I shall revert to the example of food. I regard as normal the manner in which the sated person responds to the smell of food. Here the reflex is weak—the muscular movement is barely perceptible (when satisfaction is complete it may be even null). Compared with the normal, the reflexes taking place both in the hungry and the oversated person are, of course, very acute, i.e., in both cases the reflex movements are strong. It is clear that, physiologically, aversion is the same intensified reflex as pleasure.

Consequently, the anatomical scheme of fright is equally applicable to the explanation of reflexes caused by sensual pleasures.

I feel that despite the foregoing the reader is still not convinced that absolutely all involuntary movements in the human body can be explained by means of the above-mentioned anatomical scheme. Let me try to prove that this is actually the case. Separate examples of involuntary movements taken at random cannot prove anything; indeed, it is impossible to consider all the examples since there are millions of involuntary movements. If we omit even ten cases, the sceptic would be justified in saying that precisely these ten do not fit into our scheme. The question, therefore, should be considered only from the most general point of view. And that is what we intend to do.

Properly speaking, we have divided all involuntary movements into two principal categories: pure reflexes, i.e., cases when the activity of accessory mechanisms inhibiting or intensifying the reflex movements does not interfere with the phenomenon, and reflexes with a predominant activity of the intensifying accessory mechanism, i.e., reflexes caused by fright and sensual pleasure. There is no need to dwell on the first category. It is clear that it includes phenomena of movement exhibited by people in a state when the brain is, as it were, excluded, such as sleep, alcoholic intoxication, somnambulism, deep concentration on a particular thought with resultant abstraction from all external influences, etc. Here the psychical element is completely absent. But is it possible—the reader may ask—that fright and elementary sensual pleasures are the sole psychical elements of the second vast category of involuntary movements? Yes, that is exactly the case, if by involuntary movements in the strict sense of these words one implies —as we do—only those movements that are known to science and society as "instinctive", i.e., phenomena in which there is no room for reason or will.* The explanation is this: All instinctive movements in the animal body without exception are aimed exclusively at preserving the integrity of the indivisible organism (only the sex instincts lead to the maintenance of the species as a whole). Preservation of integrity is fully ensured if the indivisible organism avoids noxious external influences and enjoys pleasant (i.e., useful) influences. Fright helps to avoid the first, while pleasure is the spur to the second.

This concludes my analysis of the quantitative side of involuntary movements. The reader has seen that almost half of all the external manifestations of the cerebral activity are explained by a very simple mechanical scheme. It is true though that in reality the phenomena are immeasurably more complex than in our scheme. Whereas most involuntary movements manifest themselves not in a single muscle fibre and not even in a single muscle, but in groups of muscles, in our scheme the complex phenomenon is reduced to the activity of a single

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* In view of this, cases of the following kind should be excluded from this category: A humane, kind person, a non-swimmer, is walking along a river bank and sees a person struggling in the water; without hesitation, he plunges into the water and is drowned in attempting the rescue. People will, probably, say that this was an involuntary movement. But it is impossible to agree with that. The man jumped into the water because he was humane and kind. Hence, a thought must have flashed through his mind before he acted.

nerve fibre and of the nerve cells linking these fibres. Nevertheless, a complex phenomenon can be essentially explained by our scheme because it shows the activity of physiological elements comprising the function of whole groups of nerves and muscles.

§7. It would be opportune now to describe the qualitative side of involuntary movements; but the reader must first be acquainted with the viewpoints, now accepted in science, concerning the manner in which the activities of separate reflex elements are combined to form a complex reflex movement, i.e., a movement involving larger or smaller groups of muscles. I have already said that a reflex element is merely a combination of a primary sensory nerve fibre and a primary motor nerve fibre connected by two nerve cells; consequently, the activity of this element is confined only to those muscle fibres which are connected with the given motor nerve fibre. Anatomy, however, shows that in the human body and in the animal body there is no muscle which would be innervated by a single nerve fibre; hence, the activity of even one muscle necessitates the combined activity of several reflex elements. How is this combination effected?

Only a microscopic investigation of the spinal cord could produce an answer to this question, since the above-mentioned elements (i.e., the primary nerve fibres and the nerve cells) are so minute that they are invisible to the naked eye. Unfortunately, the microscope, which has rendered great service in the study of the animal body, is of no help in the solution of our question: so far it has not been able to ascertain the form of the linkage between the nerve cells. Because of this, the existence of this linkage is accepted by science not as a proved fact, but as a logical necessity. Indeed, *without this intercellular linkage it would be impossible to explain the origin of even the simplest reflex.*

The matter is different if we pose the question in the following way: are all the reflex elements in the body uniformly linked so that there is no nerve cell in the spinal cord which would not be connected with all other nerve cells; or are the latter distributed in the spinal cord in groups connected with each other only in definite ways? Formulated in this way, the question can be tackled experimentally; and experiments on decapitated animals (frogs) indicate that the reflex elements are linked in the second of the above-mentioned ways. The entire body of the animal can be divided, for example, into four main reflex groups: the head group (the skin and the muscles of the head with their nervous linkage); the trunk group (the skin and the muscles of the trunk with their nervous linkage); the group of the upper extremities; and the group of the lower extremities. Each group can, when separated from the others (by decapitation and by transection of the spinal cord) act independently, but at the same time it is linked with the other groups in a definite way. For example, the group of excised upper extremities of the frog can be induced to react to stimulation of the skin of these extremities by a forward movement, in the direction of the head, as well as a backward movement in the direction of the hind legs. But if we consider this group in conjunction with all other parts of the body, we shall see that the movement of the upper extremities in the direction of the head can be induced by stimulation of any point of the skin situated above them, whereas stimulation of any point of the skin on the trunk and lower extremities below the upper extremities induces movement of the latter in the opposite direction. If we consider the group of lower extremities of the frog from the same point of view, we will see that stimulation of any point of the skin above the hind legs causes the latter to move upward, i.e., towards the point of stimulation. Consequently, all the points of the skin on the frog's head are reflexly linked with the muscles which move the upper and lower extremities upward, and all the points of the skin on the belly are linked with the muscles moving the fore extremities downward and the hind extremities upward, etc. The interconnection of the reflex groups can be even more definite: if, for example, we smear the skin of the belly of a decapitated frog with acid near the middle line of the body, then the leg will move upward in the direction of this line (i.e., towards the point of stimulation); but if we smear the side of the belly, the leg, being raised again, will move in another direction. In short, every point of the skin is more intimately and extensively linked with the muscles of its group, its connection with the neighbouring groups being confined to a very limited number of motor organs.

The connection of the spinal cord with the brain (namely, with the medulla oblongata) provides conditions for group combinations of the reflex elements of the trunk and extremities. It is believed that certain elements send processes from the spinal cord to the medulla oblongata where they terminate in mechanisms that are independent of all other central formations. These mechanisms, brought into action by sensory excitation, always produce complex reflex movements and, naturally, only in those muscles whose reflex elements project processes to the mechanism excited at the given moment. Because of this, every movement of this kind acquires a strictly specific character, and is designated by a special name even in everyday life. To this category belong, for example, the complex reflex movements of sneezing, coughing, vomiting, swallowing, etc. As we shall see later, these reflex movements (with the exception of swallowing) are effected by the trunk muscles and are always invariable as to their external nature (i.e., as to the muscles which participate in them) even when the site of application of the sensory stimulus by which they are caused is changed. Moreover, all these neuro-muscular mechanisms are inborn: an infant is able to cough, sneeze and swallow immediately upon birth. The act of sucking also belongs to this category of complex movements, although the muscles of the lips, tongue and cheeks which participate in it are innervated not from the spinal cord, but from the brain. Indeed, everybody knows that a new-born child is able to suck, i.e., to combine the movements of the above-mentioned parts of the body in a definite way. Moreover, it is a well-known fact that the activity of this complex mechanism in the infant is called forth by irritation of the lips; put, for example, your finger, or a candle, or a wooden stick between the child's lips, and it will begin to suck. Try to do the same with a child three months after it has been weaned, and it will no longer do so; however, the ability to produce sucking movements at will is retained by man for life. These are highly remarkable facts; on the one hand, they show that conduction of sensation from the lips to the central nervous mechanisms which produce the sucking movements apparently ceases in the child after weaning; on the other hand, they indicate that the integrity of this conduction is maintained by the frequent repetition of the reflex in one and the same direction.

Finally, this group of mechanisms includes the nervous apparatus which co-ordinates the movements of the hands and legs in walking. This apparatus, which in vertebrates is situated in front of the medulla oblongata, is in some animals (for example, in the horse, the chamois, and others) an inborn apparatus; it can be brought into action by stimulation of the skin. In grown-up animals it is, apparently, induced to action only under the influence of will and psychical activity; nevertheless, experiments connected with removal of the cerebral hemispheres clearly show that walking can also be a perfectly involuntary movement in animals, because only stimulation of the skin, or some other external influence can bring decerebrate animals out of the state of drowsiness. On the other hand, there are lesions of the brain when the animal begins to walk or to run irresistibly, apparently contrary to will. Physiologists even call these phenomena forced movements.

Is it not obvious from the foregoing that the walking movements of animals can be involuntary? In man the matter is, apparently, quite different: Man's walking belongs to movements which are acquired by learning, i.e., accomplished under the influence of mentality and will. Besides, everybody knows from personal experience that walking is a highly voluntary act; at any rate, it can be discontinued at any moment, accelerated, etc., at will. And yet later, when we discuss habitual movements and somnambulism, the reader will, I think, agree that in man, too, walking can be an involuntary act.*

It is also interesting to note that if a child which has just learned to walk becomes ill and remains in bed for a long time, it forgets the previously acquired art of walking. In this case the co-ordinated activity of the reflex groups which participate in the act of walking becomes deranged. This fact testifies once again to the great importance for nervous activity of frequent repetition in one and the same direction.

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* There are cases of brain diseases when the patients run unconsciously, being unable to stop, until they stumble against an object and fall.

Thus, the mechanism which is responsible for combining reflex elements into groups consists: 1) in the general connection of nerve cells with one another by means of branchings, and 2) in the connection of some of the reflex elements in the body with the central mechanisms in the medulla oblongata (and possibly in other parts of the brain) which are isolated from other mechanisms.

§8. Now that we have analysed the quantitative side of involuntary movements, we shall pass to an examination of their external character.

Unfortunately, the scientific elaboration of the qualitative side of the phenomena under consideration has hardly begun, and willy-nilly I shall have to be brief.

Here are the essential features of involuntary movements:

1) Movement rapidly follows sensory stimulation;

2) Sensory stimulation and the resulting movement more or less correspond to each other in duration;

3) Involuntary movements are always expedient. By means of them the animal tries either to retain a sensory stimulation, if it is pleasant, or, on the contrary, to escape it, if it is unpleasant, or, finally, to get rid of it, if it is very strong. All this (except reflexes of pleasure) can be easily proved on a decapitated frog, where the involuntary nature of the movements is unquestionable.

Let us suspend such a frog in the air and slightly pinch its skin in any spot. The frog will immediately react with an abrupt reflex movement; the latter will be as instantaneous as the stimulation. But if instead of pinching the skin we use an irritant, for example, sulphuric or acetic acid, the effect will be altogether different: the skin irritation will be protracted and, instead of one abrupt movement, we shall observe a long series of similar movements. These simple experiments illustrate the first two points, but at the same time they indicate the expediency of reflex movements. This last feature is manifested with particular force in such phenomena as sneezing, coughing and vomiting. In these cases a sensory stimulation starts the phenomenon: sneezing is caused by stimulation of the mucous membrane of the nasal cavity, coughing—by that of the throat, and vomiting

—by that of the rear part of the mouth cavity; and in each case the phenomenon ends with a complex reflex muscular movement in which the muscles of the thoracic and abdominal cavities are predominantly involved. Each of these complex movements actually serves one and the same purpose—removal of the cause of the irritation. Sneezing is accompanied by a rapid current of air in the nasal cavity, by which the latter is freed from its contents at the given moment. During coughing the same occurs in the larynx, while vomiting, so to speak, washes those parts of the mouth cavity which cannot be cleaned with the help of the tongue. Nobody will dispute the mechanical nature of these phenomena, since it is a well-known fact that they are not controlled by our will, that they arise inevitably as a result of stimulation. The automatic nature of coughing, vomiting, etc., is stressed by the fact that the groups of muscles acting in each case are constant, i.e., the same muscles invariably participate in the act of coughing, no matter what has caused it, just as the same muscles effect the acts of sneezing and vomiting. The matter is different in the case of complex reflex movements resulting from stimulation of the sensory surface of the skin. Here the groups of muscles participating in the reflex movements vary with the change in the conditions of the stimulation. Because of this the phenomena, actually retaining a reflex (i.e., mechanical) character, become extremely diverse; sometimes they seem even rational, i.e., based on mentality and will. I shall try to illustrate this idea by some examples and show that the seeming rationality of a movement does not preclude the mechanical nature of its origin.

Pinch the leg of a decapitated frog and it will try by means of a simple movement to withdraw this leg from the irritating agent. Smear the same leg with acid, and the frog will rub it against some other part of the body for a long time as if trying to get rid of the acid. It is obvious that the head is not necessary to distinguish between acid and a pinch. Similar phenomena are also observed in a sleeping man: slight tickling of the skin of the face invariably induces contraction of the muscles immediately beneath the point of stimulation. If this movement does not suffice to remove the irritant, the sleeping man scratches the place with his hand. In these cases the movements are still very simple, and nobody will doubt their automatic character, i.e., the mechanical nature of their origin. But here are experiments in which the reflex movements may seem to the observer more rational. Remove the entire anterior part of the brain of a frog, almost up to the medulla oblongata, and place the animal on the table. Give it time (about five minutes) to recover from the shock of the operation and then lightly pinch its leg; the frog will creep away in the opposite direction, in an endeavour to escape from the irritation. If this frog is placed in water, pinching will make it swim. It is obvious that the frog cannot reason, since the thinking part of the brain (i.e., the cerebral hemispheres, according to physiologists) has been removed; nevertheless, it reacts as rationally as in the case when the brain is intact, i.e., when it possesses will and capacity for thinking; the animal is conscious of the environment: on the table it creeps, in the water it swims. Pflüger, who studied the qualitative side of these phenomena, describes an experiment with a decapitated frog (even the presence of the medulla oblongata is not necessary in this experiment) where the seeming rationality of the reflex movements was of an even more pronounced character. A decapitated frog is suspended vertically. The skin of its belly is irritated by acid on one side, for example, the right. Under ordinary conditions the frog rubs the irritated place with its right hind leg, and sometimes also with the right foreleg if the irritated point is near this leg. But if the right hind leg is cut off, the frog will begin to rub the irritated place with its left hind leg despite the fact that this movement appears to involve some difficulty. From this one would think that a kind of intellect is located in the spinal cord of the frog. And this, of course, is true, at least to the extent that a movement arising in the spinal cord can be called rational. Not the name but the essence of the phenomenon is of importance to us, i.e., the question whether the movement is involuntary, inevitable, i.e., mechanical. The question can be easily answered. The movement is involuntary because a decapitated frog cannot perform voluntary movements. It is inevitable because it invariably follows an obvious sensory stimulation. Finally, it is mechanical by origin for the very reason that it is inevitable. Thus, the reader can see that in the cases considered by us all the reflex movements are expedient and that in some of them the expediency reaches such a degree that to the observer the movement no longer seems automatic and acquires a rational character.

On the basis of the experiments with stimulation of the skin of a decapitated frog and of the sleeping man the following general rule can be established: excitation of any point on the sensory surface of the body can induce reflex movements depending on the given conditions; these movements are diverse as to the groups of muscles participating in them, but their purpose is invariably the same—to protect the body from certain external influences. In this sense, the reflex mechanisms of the spinal cord constitute an apparatus which partly ensures protection of the organism as a whole from noxious influences acting directly on the skin. This protection is partly ensured also by the nervous mechanism of walking inasmuch as it is induced by sensory stimulation of the same skin; the existence of this mechanism in the body of the animal provides the latter with additional means of escaping from external harmful agents. If, in addition, we consider the animal's eyes and ears, i.e., the visual and auditory sensations as connected with this mechanism, we shall see that the animal is enabled to avoid even remote noxious external influences. It is precisely from this point of view that we should consider vomiting which frees the stomach from irritating substances, coughing and sneezing which remove foreign substances from the throat and nose respectively, as well as the acts of defecation and urination in response to the stimulation of the rectum and the urinary bladder. All these movements are involuntary and at the same time expedient, because they are aimed at ejecting noxious agents from the body.

The nervous mechanisms, by means of which the body frees itself both of external and internal noxious influences form, in the aggregate, part of the apparatus that ensures the intactness of the organism as a whole, an apparatus whose activity reveals the presence in all animals of the instinctive (i.e., involuntary) sense of self-preservation.

§ 9. Nobody, of course, will doubt the self-preservation instinct in man. And everyone has undoubtedly heard of human actions which can be explained only by the presence of this instinct.

Facts are even cited which indicate that the interference of reason sometimes harmfully affects the expediency of the instinctive movements. It is well known, for example, that somnambulists climb up roofs in sleep, with a dexterity that is inconceivable in fully conscious persons. It is also said that the tipsy horseman passes dangerous parts of the road more skilfully than the sober rider. In these cases the presence of consciousness can affect the expediency of the movements, because it evokes fear which causes a new series of involuntary movements interfering with the expedient ones. In any case, the reader will appreciate that sometimes involuntary movements are not only equal to conscious movements in seeming rationality but even surpass them in this respect. The main point is that involuntary movements are less complex and, consequently, their expediency is, so to speak, of a more direct character.

Thus—I repeat—the apparent rationality of a movement (from the point of view of preserving the body) does not exclude the mechanical nature of its origin.

Those with a disposition towards strict systematisation may say that the above-mentioned examples of the somnambulist and the tipsy horseman are irrelevant in the case of involuntary movements. Indeed, as I have already said, one of the features of an involuntary movement is its independence of mentality, of thought. But in the last two examples the absence of thought can still be doubted, although the somnambulist and the drunken man usually do not remember what happened to them in sleep or in the state of intoxication. In support of his objection the reader might cite the example of the sleeper who screams and moves under the influence of a terrifying dream, though upon awakening he has no recollection of the dream, or the example of the delirium and violent movements of a maniac during an attack of his disease. In all these cases a psychical element interferes with the phenomenon, that is, some kind of imagination, which, of course, is as real as any reasonable notion.

The objections would be justified if I included all the external manifestations of the somnambulist and the drunk in the category of involuntary movements. That, however, is not my purpose; I designate as involuntary only the remarkable ability of equilibration displayed by a person, if he is not an equilibrist, only in the absence of consciousness. Consequently, if a certain movement is impossible in the presence of thought and, on the contrary, is effected exclusively in the absence of consciousness, the movement can be only of an involuntary, reflex, instinctive nature. I would ask the reader to pay special attention to the following aspects of the examples just cited.

1)*Involuntary movements may be combined with movements induced by what is usually called definite psychical notions* (for example, the balancing of the somnambulist and of the drunken rider is connected with the acts of walking and horse-riding, which are caused by a certain psychical motive).

2) *Involuntary movements may represent a series of acts* (for example, during the dangerous walk of the somnambulist, or during the ride of the inebriated horseman); these acts *are expedient for preserving the body and are, therefore, rational from this point of view.*

3) Finally, *there are cases of involuntary movements where the presence of sensory excitation, which gives rise to a reflex, is understood, though it cannot be clearly determined.*

All these aspects have such an important bearing on our discourse that I deem it necessary to dwell on them in greater detail.

The equilibration, or involuntary movement of the somnambulist may be combined with walking—an act caused by a psychical motive and not, therefore, instinctive. This is absolutely true for the case where the maintenance of balance (equilibration) can be separated from the act of walking, i.e., from the periodical movement of the legs. But what about those cases where the entire equilibration consists exclusively in firm and correct walking, when the somnambulist, for example, fearlessly crosses a narrow plank which is thrown over a yawning precipice and which hardly gives room for his feet? A person who is not an equilibrist would never do this in a conscious state. Consequently, according to our definition, this movement, i.e., walking, should be included in the category of involuntary movements. Let the reader thoroughly consider the foregoing, and he will undoubtedly understand that this is by no means juggling with words, but real truth. How, then, is it possible to regard as involuntary an act such as walking which is learnt in childhood and which, consequently, develops under mental influence? The following argument may reconcile us to this idea. Man can rightfully be placed on a level with animals as regards the structure of the central nervous mechanism of walking, since the young of some animals are also unable to walk immediately after birth and have to learn this art. Nevertheless, in these animals, too, the nervous centres of walking are located not in the cerebral hemispheres where impulses are originated for all the so-called voluntary movements, but in the mid-brain (in the frog, for example, in the medulla oblongata); hence, the same must be true for man. It follows, therefore, that man's walking may also be an involuntary act. But how, then, do we explain the continuous nature of walking? What are the impulses, i.e., the sensory stimuli which cause this series of periodical movements? It has been stated above that a reflex movement corresponds in duration to the stimulus which evokes it. I shall now give a definite answer to that question: in the process of walking sensory excitation accompanies every step, that is, every time the foot contacts the surface on which the person is walking sensation of support arises; excitation is also caused by sensations which arise during the contraction of corresponding muscles (the so-called muscular sense). The importance of these sensations in the act of walking can be best illustrated by the example of patients suffering from loss of sensibility in the skin and muscles of their legs. In the day-time, when they see the floor, they are able to move with difficulty, because visual sensations compensate to a certain extent for the loss of tactile and muscular sensations; but in the dark these people completely lose the ability to move. Feeling no support under their feet, they cannot make a single step, nor can they stand even for a few seconds without falling. If the reader has ever missed his footing while walking he can easily visualise the state of these people. You are walking, say, along a dark corridor and quite unexpectedly come across a staircase which leads downwards; your foot suddenly falls, as it were, into an abyss; your fright disappears only when you regain firm support under your foot. In people who suffer from paralysis of the skin and muscles this sensation of falling into an abyss makes itself felt the moment they close their eyes, hence they are unable to make even a single step. Besides, how can the patient know in the dark when his foot has left the floor and when he must place it on the floor again. In performing these movements which are repeated at each step by each foot we are, apparently, guided exclusively by sensation. It is noteworthy that the gait becomes much more deranged owing to loss of muscular sense (a sense, which is more vague[12] and hardly reaches consciousness) rather than to paralysis of the considerably more pronounced tactile sensations.

The reader may object to this pathological example by asserting that fright alone prevents walking in the dark. Although at first sight this objection seems to be valid, in reality it is groundless. Indeed, watch an absolutely normal person walking on even ground, uphill, or along a road full of pot-holes. In all cases the gait of the same person is different. This means that he adapts the movements of his body to the particular conditions of the locality in which he is moving, and which can be ascertained only by means of his visual sensations or the sensations of his feet. But imagine a person who is absolutely unable to sense the surface of the road along which he is walking; how, in these circumstances, can he adjust his gait?

Thus, in some cases walking can be an involuntary movement. Since it belongs to the category of movements which are acquired by habit and learning, i.e., movements which develop under mental influence, it can be assumed that all such movements may become involuntary, provided, of course, the mind (at least in relation to these acts) is in a state similar to that observed in somnambulists and intoxicated people.

Unfortunately, we cannot describe this state of mind physiologically. Observations on phenomena of intoxication, brought on by alcohol, opium, chloroform, etc., make it only possible to state with certainty that in all these cases, just as in normal sleep, somnambulism, delirium and attacks of mania, *normal* sensibility is dulled to a considerable degree if not eliminated altogether (recall the insensibility to acute pain observed in persons under chloroform, alcohol and opium, or the lowered sensibility of a man in a deep sleep, to every external influence, etc.).I do not maintain that this decline of *normal* sensibility fully summarises the states of intoxication, sleep, etc. (of course, only with regard to the state of the brain); however, I think that the decline constitutes the chief and most important element of the states under consideration; in any case, physiological investigations do not reveal in the nervous activity of drunkards, sleepers, maniacs, etc., any changes as manifest as the decline of sensibility. Now let us see what ensues therefrom.

If sensibility is lowered, this means that the functioning of the parts of the brain, the intactness of which as shown by physiological experiments is indispensable for the emergence of sensations (and consequently of consciousness), has weakened, or has ceased altogether (when sensibility and consciousness are fully lost). In both cases the effect produced by the sensory stimulus (sound, light, a prick of the skin, etc.) is either very dull or does not reach consciousness at all, though it is able to induce a series of movements in the body. And these movements are, of course, involuntary according to the mechanism of their origin.

For the sake of greater clarity we will examine somnambulism from this aspect. The beginning of the act is a certain sensory stimulation which is not susceptible of definition; its continuation is a sort of psychical notion which is vague and dull, owing to decline of sensibility; and the end is a climb over the rooftops. Does this not strikingly resemble the mechanism of fright? The only difference is that in the latter case the fright is the psychical element, while here it is probably a psychical formation of a higher order, some kind of notion. But it is only a *probability*; besides, the psychical notion is, apparently, felt less distinctly than fright. Consequently, both phenomena are indisputably similar.

At the same time this proves that all movements performed during normal sleep and in a state of delirium, even if they accrue from what is commonly called "dreams", i.e., from definite psychical acts, are involuntary in the strict sense of the word, that is, reflex movements.

Since the entire psychical life of a person can be reproduced in sleep and in delirium (of course, in a distorted form), all movements acquired by learning under the influence of the mind and all habitual movements can become involuntary as regards the mechanism of origin. I shall not cite many examples in support of the aforesaid; let me limit myself to two that I witnessed myself. In my student days I once saw in a Moscow clinic a cook who had fallen on his head from a height and died without recovering consciousness. Early in the afternoon when the physicians were making their usual rounds, that is, at the time when before his accident the patient would be preparing meals, he could be seen making movements with his hands as if he were chopping meat with two knives, as is usually done by cooks. Here we had a movement which had been acquired by habit before the accident and which, undoubtedly, was a reflex movement by mechanism of origin. This example also indicates what it was that constituted the beginning of the reflex act; in the given case it was a sensory excitation (caused, of course, by the diverse properties of noon, inasmuch as these properties can act on the sensory nerves); the stimulus, however, cannot be exactly determined.[13] Now for the second example. A close acquaintance of mine had a habit of folding his fingers in a most peculiar manner when absorbed in thought; this habit was quite familiar to me. I happened to be present at his death, and when all the external symptoms showed that he had lost consciousness, his fingers became folded in his usual way.*

Thus decline of sensibility is a highly important factor in the brain functioning of sleepers, drunks, somnambulists, etc. Let us now see whether this factor plays any role in the functioning of the same organ under quite different conditions.

As is known, in the absent-minded person, or in a person whose mind is concentrated on a strictly definite thought, the capacity for sensation is in many respects (though not in all)

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* There is a highly illuminating experiment with a decapitated frog which shows how the habitual movements of the normal frog are manifested in the nature of its reflexes upon decapitation. A decapitated frog sitting with its hind legs tucked under its belly will, in response to a pinch on the legs, immediately extend them. On the contrary, if the hind legs are extended, the pinch will cause the frog to bend them and to pull them up under the belly. If the pinch is a strong one, the frog will in both cases make a jump. The point is clear: under normal conditions any pinch would impel the frog to escape; but in the given case its reaction is proportionate to the strength of the sensory stimulation: when it is weak, the frog makes, as it were, a half jump. Hence, when the legs are bent it extends them, and, on the contrary, when extended it bends them. Essentially both movements represent the beginning of a jump.

more or less dulled. If, for example, a person is listening attentively to something, he hardly notices what is going on before his eyes, and vice versa.

In people possessing the faculty of profound concentration, sensibility to external influences is sometimes dulled to a surprisingly high degree. It is said, for example, that a man in the grip of a fixed idea feels neither cold, hunger nor acute pain when his mind is concentrated on the idea. Generally speaking, dulled sensibility to certain external influences is always observed in man when his mind is preoccupied. On the other hand, it is a well-known fact that it is precisely those influences to which the sensibility is dulled that induce movements with particular ease. These movements are either completely unnoticed by the individual who is absorbed in his thoughts, or they produce in him very vague sensations. In any case the movements are involuntary to such a high degree that even the layman usually calls them "automatic". And it will be appreciated that from the point of view of their mechanism of origin all such movements must be included in the category of involuntary, no matter whether they produce sensations or not.

From what has been said the reader will probably agree that habitual contractions of the muscles of the body which generally impart a definite mould to each individual and which in most cases are fully independent of mind and will, also belong to the category of reflexes despite the fact that the two afore-mentioned factors (mind and will) participate in their development. Such, for example, are the habits of an open mouth, protruding lips, blinking, holding the head sidewise, nail biting, nose picking, winking, etc.

From the point of view of their mechanism these movements are always involuntary, if they are effected without participation of the intellect.

I have now exhausted the sphere of involuntary movements in our interpretation of the term.

To conclude the chapter I shall briefly summarise the results of our study of these phenomena.

1) Every involuntary movement is the result of a more or less distinct excitation of a sensory nerve.

2) A sensory excitation which induces a reflex movement, may, at the same time, evoke certain conscious sensations; the latter, however, are not indispensable.

3) In a pure reflex, which is not accompanied by any psychical elements, the relationship between strength of excitation and intensity of the resulting movement remains the same in the given conditions.

4) If the reflex is complicated by a psychical factor the relationship may fluctuate in one or in the other direction.

5) The reflex movement comes quickly in the wake of the sensory excitation.

6) The reflex movement more or less corresponds to the sensory excitation in duration, especially if the reflex is not complicated by the psychical elements.

7) All reflex movements are expedient from the point of view of preserving the integrity of the organism.

8) The specific properties of involuntary movements described above are equally peculiar to the simplest and to the most complex reflexes—to abrupt movements of several seconds' duration as well as to a series of successive reflexes.

9) Frequent repetition of a reflex in one and the same direction is caused either by the presence in the body of a definite inborn mechanism (for example, the mechanism of sneezing, coughing, etc.), or is the result of learning (for example, the act of walking) which is achieved with the participation of the intellect.

10) If normal sensibility is dulled in the sphere of one, several or all senses (sight, hearing, smell, etc.), then all the movements caused by these senses—no matter whether acquired by learning or not, whether connected with psychical notion or devoid of it—are, invariably, reflex movements from the point of view of the mechanism of origin.

11) This mechanism is formed by sensory and motor nerves, by cells located in the cerebral centres and originating these nerves, as well as by processes which these cells project into the brain and along which the latter influences the reflex movement, intensifying or weakening it.

12) The functioning of this mechanism constitutes the reflex.

13) The mechanism is brought into action by excitation of the sensory nerves.

14) Hence, all involuntary movements are mechanical in origin.

All the above-mentioned properties of involuntary movements must be kept in mind if we do not want to get lost in the extremely intricate world of voluntary movements to which we shall now proceed.

Chapter Two

VOLUNTARY MOVEMENTS

Solving the question of the onset of a psychical act.—Inhibition of conscious movements.—Emotions.

§ 10. Before turning to voluntary movements I must warn the reader that the lack of physiological experience in this sphere will be felt very frequently and that at times I shall have to deviate from the role of physiologist. I believe, however, that even in these difficult cases I shall adhere to the custom of naturalists—frankly admit my lack of knowledge and frame my hypothesis only on the basis of strictly established facts. Hence, much will remain unsaid; however, that which I shall expound will be fairly well grounded. I hope that the complexity of my task will dispose the reader to show forebearance to this first attempt to interpret the phenomena of voluntary movements as the machine-like activity of a relatively simple mechanism. My task, then, will be: to explain by means of the anatomical scheme already known to the reader the external activity of a man with an ideally strong will (it should be borne in mind that this external activity always boils down to muscular movements), acting according to some high moral principle and perfectly conscious of everything he does—in short, activity which is voluntary in the highest possible degree.

Thus, we have to prove:

1) that this particular human activity consists of reflexes which begin with sensory stimulation, continue in the shape of a definite psychical act and end in muscular movement;

2) that given definite external and internal conditions, i.e., the environment in which the action takes place and the physi-

ological state of the individual performing the action, one and the same sensory stimulus inevitably calls forth the other two elements of the phenomenon and always in the same direction.

But before outlining a scheme which may help us to accomplish these tasks, I shall try to show in a few words that the final component of any voluntary act—muscular movement—is essentially identical with the activity of muscles in pure reflexes, i.e., in elementary involuntary movements. Physiology maintains that there are no special motor nerves and muscles for voluntary movements. The same nerves and muscles which produce the purely involuntary movements act also in the case of voluntary movements. If there is any difference between the two acts it is solely in the external character of muscular contraction, i.e., in a more or less rapid contraction of one muscle and in a greater or lesser contraction of another. The reader is already aware that the countless animated features of complex muscular movements can be reduced to diverse combinations of the above-mentioned mechanical properties of muscular activity.

Consequently, that part of the reflex mechanism which consists of the motor nerve and muscle is likewise capable of producing voluntary movements.

Let us first try to find out how a voluntary movement is evoked, i.e., how excitation of sensory nerves begins.

Then we shall establish whether the process projecting into the brain and inhibiting reflexes, participates in the voluntary movement and how this participation is effected.

We shall investigate the same with regard to similar processes which intensify reflexes.

And if all the features of the most voluntary of all voluntary movements are established as a result of this examination, we shall consider our task as having been completed.

The reader will require first of all a list of the properties of a typical voluntary movement. Here is a key which will help in the matter: the reader should keep before him the properties of involuntary movements enumerated at the end of the preceding chapter; he should simultaneously clearly imagine the manifestation of a certain external activity of a person with an ideally-strong will, one who acts in accordance with high moral principles and who is fully conscious of every step he takes.

1) The movements of this person are not based on perceptible sensory excitations (usually such people are not diverted from their chosen path even by the most terrifying forces of environment and are able to suppress all natural instincts).

2) The movements of such an individual are determined exclusively by the highest psychical motives, by the most abstract notions, such as welfare of mankind, love of his country, etc.

3) Will is able to reduce the external activity of man to absolute dispassion (this proposition chiefly ensues from self-observation, i.e., to the fact that man is conscious of this ability); but the external activity can be voluntarily intensified only within certain limits. Enthusiasm, for example, with all its external manifestations, is beyond the control of human will.

4) The moment of the onset of the external movement depends on the will, provided the psychical factor giving rise to the act is not complicated by emotion (this proposition, too, chiefly ensues from self-observation).

5) The duration of the external movement is also dependent to a degree on will (according to self-observation), and is determined by greater or lesser fatigue of the nerves and muscles. A psychical motive of an exceedingly passionate nature always brings the external activity to the peak, admitted by the organisation of the nerves and muscles.

6) Highly voluntary movements often contradict the instinct of self-preservation. They are expedient only from the point of view of the psychical motive which causes them.

7) The combination of individual voluntary movements into groups is directed by will (according to self-observation). Here, too, absence of emotion in the psychical motive is an indispensable condition.

8) Voluntary movement is always conscious.

The reader will gather that I have described the voluntary movements in the same way as is done by educated people who are aware of their own sensations. It will be appreciated also that I have exaggerated rather than minimised the concepts of volition now prevailing in society. I have done so, on the one hand, because I am dealing with the highest manifestation of volition, and, on the other, because I did not want prematurely to approach this phenomenon from the standpoint of an observer, believing, as is customary, in the voice of self-consciousness. I will now, however, approach the problem critically and proceed to examine the first point.

§ 11. Is it really the case that voluntary movement does not derive from sensory excitation? And if there is sensory excitation, why is it disguised in typical manifestations of voluntary movement?

I must warn the reader that my answer will not be a brief one, because instead of directly analysing the highest type of voluntary activity I shall have to trace its development from birth and investigate the less perfect types.

The reader will, of course, insist that I should first of all justify this method, i.e., prove that it will really lead to our goal.

Here are my arguments in favour of it. All people without exception judge a man by his external activity. But character, according to the generally accepted point of view, develops gradually from the cradle, and it is contact with life, i.e., upbringing in the broad sense of the term, which is of greatest importance in this development. Hence, voluntary movements develop in the same way.

Man is born with a tiny number of instinctive movements in the sphere of the so-called animal muscles, i.e., muscles of the head, neck, arms, legs, as well as those muscles of the trunk which cover the skeleton from the outside. He can open and close his eyes, suck, swallow, scream, cry, hiccup, sneeze, etc. All other movements of the arms, legs and trunk are undoubtedly also of a reflex origin.

The sphere of sensations in the new-born child is also limited, because the infant cannot see, hear, smell or touch. This is easily proved: these acts require the activity of definite groups of muscles which cannot be controlled by the new-born child. For example, to see an object before the eyes it is essential that the optical axes of both eyes should cross on the object; but this can only be effected with the help of the muscles which turn the eyes in all directions. The new-born child cannot do this: its look is always uncertain, i.e., it is not fixed on definite objects.

Neither, of course, has anyone ever observed smelling movements in an infant. But with the passage of time the child learns to perform these movements. I shall now dwell in detail on the process by which the child learns to see objects clearly, since it serves as an example of elementary training of the senses.

But before doing so I shall dwell on some facts relating to the structure of the eye, otherwise the reader would have difficulty in understanding me.

At the bottom of the eye, opposite the pupil, the optic nerve ends in the shape of a continuous membrane. Objects situated before the eye are impressed on this membrane just as on a photographic plate, these impressions being an indispensable condition for vision. However, not all parts of the membrane are equally sensitive to light; the most powerful sensation of light arises only when the image of the object falls on that part of the membrane which lies on a line determined in the following way: if an adult looks with both eyes at an object situated before him and if straight lines are drawn from the object to the centres of his pupils and then mentally prolonged into the eye, the lines will fall on that part of the membrane which is most sensitive to light. These lines are known as the optical axes. Consequently, to direct the optical axes of both eyes to the given object, i.e., to learn to see it clearly, means focussing the eyes in relation to the object in a way that gives the clearest possible perception of the object. The process by which this art is acquired is obvious. Brightly coloured objects are usually held before the child's eyes; roaming in all directions the eyes receive light sensations of varying intensity; the strongest sensations arise when the optical axes fall on the object. The infant's brain is so constructed that the brighter the light the greater the pleasure. Because of this the child, without thinking, i.e., involuntarily, tries to keep its eyes in the position from which it derives the greatest pleasure. This is repeated not once or twice, but thousands of times until the art of seeing objects clearly is mastered.* Muscular movement, which here plays a decisive role, is always an involuntary act developing in the given direction under the

* For the sake of brevity I omit the role of muscular sensation, as well as the complication of the process by double images. The omission, however, does not affect the clarity and soundness of the point.

influence of habit, i.e., frequent repetition of the movement in one and the same direction. Consequently, the primary act of vision even in the adult is involuntary, though it is acquired by learning.

The structure of the optical membrane, certain parts of which perceive light better than the other parts, is responsible for another involuntary act the psychical aspect of which, in its highest degree, is described as "attention in the sphere of visual sensations". It is expressed by the clarity of perception of the image on which the attention is focused (at which the person is looking, or to which his optical axes are directed), as well as by decline in sensibility to the surrounding objects sometimes resulting in their complete disappearance from the field of vision. I will cite an example concerning the physiology of the eye, one that convincingly proves what I have just said. If the reader has never read anything about the physiology of the eye, he will, naturally, doubt my statement that when we look closely at a certain object all other objects lying nearer or farther than the fixed one seem doubled. He can convince himself easily enough: it suffices to pay attention to this phenomenon and focus one's look on a definite object without moving the eyes from one object to another. Once you become convinced that what I have said is correct, try to recall whether there were moments in your life or in the life of any of your acquaintances (with normal sight, of course) when conscious efforts had to be applied against double perception of objects in the vicinity of the one on which the eyes were focused. No one has ever experienced such moments; hence, the disappearance of these objects from the field of vision is due to a certain organic cause which does not depend on will. Hence, that which is described as attention in the sphere of visual sensations is an involuntary act. In essence, visual attention is simply convergence of the optical axes of the eyes on the object observed. Attention to an object situated before the eyes evokes, according to experimental psychology, a clear sensation; according to physiological investigations, this sensation includes the colour, configuration and corporeity of the object, which means that it can be rightfully raised to the level of *notion*.

Thus, the development of *notion* does not depend on will. This psychical act is caused by stimulation of that part of the optical membrane which is most sensitive to light.

Let us now see what follows sensory stimulation of the optic nerve.

An impression of light always produces in the infant a more or less extensive reflex muscular movement. When, for example, a brightly coloured object appears before its eyes, it yells, laughs, flails its arms, legs, and the entire body; clearly, then, reflexes from the optic nerve are possible in all the animal muscles of the child's body. This is a highly important factor: it means that infinitely diverse body movements, induced by endless combinations of the muscles into groups, can develop under the influence of visual sensations; besides, this condition makes possible the association of visual sensations with the tactile and muscular sensations. Actually the hand is the chief tactile organ in man; by means of reflexes from the optic nerve the hand is brought into motion and when encountering external objects calls forth tactile sensations in the broad sense of the word. A long period must pass, however, before the child learns to feel with its hand; at first it cannot even hold an object which is placed in its hand, although the hand clutches at the object involuntarily. In any case, it is a well-known fact that visual sensations are easily associated with tactile sensations, with the result that in our notions of the form of bodies (round, cylindrical) as well as of their smoothness or roughness, etc., both kinds of sensations merge. Moreover, it is clear that in essence these complex notions do not differ from the most elementary sensations. But before going further I shall enumerate the processes which take place in the development of a complex optical notion.

Impression of light. Vague sensation of light. Contraction of the muscles which move the eye and adapt it to distance.	First Reflex
The action of light continues. Clear sensation. Movement of arms and legs.	Second Reflex

The hand encounters the visible object.

Hence:

Tactile impression and— Tactile sensation producing the movement of the hand which grasps the object	Third Reflex

This example does not necessitate further explanation. Any optical notion already complicated by tactile sensations can be further complicated by sensations belonging to the sphere of other sense organs. Among these associations the optico-acoustic plays a particularly important role in the development of man. So let us now pass to the process by which hearing is trained.

Aural attention, or listening, is an involuntary movement acquired by learning. Its outward manifestation is approximately the same in man and animals: the ear is placed in a position which is most favourable for the action of sounds on the eardrum. This act is similar to the act of convergence of the optical axes on an object in vision. Aural attention is manifestly confined to this external act when separate simple sounds, even the faintest, are perceived. It is a different matter when the sounds are combined into words. In this case the mere external act of listening does not suffice for clear perception. You have, for example, learned the English language perfectly; you understand what you read and pronounce the words correctly, but you have never lived among Englishmen. When you listen to their speech, you do not understand a single word, no matter how intently you listen; but should you spend a month among English people you would soon begin to understand every word. How this occurs we shall see later; but now the reader will agree that attention of this kind is also a matter of habit and a perfectly involuntary act.

From what has been said it is clear that the hearing of the new-born child is approximately in the same state as, say, the hearing of a Russian peasant in the society of Englishmen. In both cases a long time passes before they learn to listen to words. In the case of the child this state is expressed in the fact that it begins to babble. To put it in another way, reflexes from the organ of hearing to the muscles of the breast, larynx, tongue, lips, cheeks, etc. (i.e., muscles participating in speech), hitherto unco-ordinated, begin to assume definite shape. As is known, persons who are deaf from birth never learn to combine sounds into words; this proves what I have just said in a most convincing way[14]. However, the faculty of hearing words is but one of the conditions necessary for articulating sounds. Recall how much time passes from the child's first word "mamma"* until it begins to speak. A decisive role in speech development is played by the child's instinctive desire to imitate the sounds acting upon its ear—by mimicry which in respect of hearing it shares, among animals, particularly with birds. The process of articulation of sounds and their combination into words is, of course, similar in the child and in the parrot. Essentially it consists in association of sensations caused by the muscles of speech during contraction with aural sensations induced by the sounds of the individual's own speech. In any case there is no doubt that such acts, being involuntary as to the mechanism of their origin, belong to the reflexes acquired by learning.

In the vocabulary of the child, as well as of the overwhelming majority of adults, there is not a single word that has not been acquired by learning—either orally, or in written form. That, I think, needs no proof; it suffices to compare, say, the vocabulary of a ten-year-old boy who is being taught foreign languages and other subjects, and the vocabulary of an eighty-year-old illiterate peasant who has never left his native village.

Thus, the process of articulating sounds is actually the same in the child and in the parrot. But what a difference in their faculty of speech! While the parrot learns to pronounce only a few phrases in ten years, the child learns thousands. The parrot pronounces the words in a purely mechanical way, whereas the speech of the child, even at a very early age, bears, so to speak, an intelligent character. The latter is determined mainly by the association of aural impressions with visual and tactile ones;

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* From the standpoint of the mechanism of its origin the word "mamma" is the simplest; to produce the syllable *ma* it is sufficient simultaneously to make a sound with the larynx and to open the mouth, while all other muscles regulating sound and speech remain absolutely inert.

the more diverse the forms of this association, the more pronounced is the intelligence of speech.

When an animal or a child hears a sound, the reflexes from the stimulated auditory nerve include the turning of the face in the direction of the sound and the movement of the muscles which turn the eye-ball. The first movement is the act of listening, since sound acts best on both ears when the face is turned towards the source of the sound; the second movement leads to visual sensation. It is these two successive reflexes, acquired by learning, which constitute the elementary form of the visual-aural association. Consequently, the process is the same as in the combination of visual and tactile sensations. This can be illustrated by an example. I shall revert to the example of visual-tactile association and introduce into it an aural sensation (see page 49). Let us suppose that the object grasped by the child is a bell. In this case along with the muscular-tactile sensation caused by grasping the bell there takes place stimulation of the auditory nerve, followed by the sensation of sound and by a more or less extensive reflex movement. Thus a fourth reflex is added to the three previous ones. If this process is repeated many times, the child begins to recognise the bell both by its appearance and by its sound. Subsequently, when, as a result of learning, the reflexes from ear to tongue take definite forms, the child begins to call the bell "ding-ding". The same occurs when it learns the real name of the bell, because this name, like "ding-ding", is a conditional sound. But what is the sequel: the successive reflexes acquired by learning lead to a perfect notion of the object, to *knowledge in its elementary form.* Indeed, the scientific knowledge of external objects is simply an infinitely broad *notion* of each of them, i.e., the sum of all possible sensations evoked in us by these objects under all conceivable conditions.

I shall not touch on the subject of training taste and smell, since to do so would be to repeat what I have already said with regard to other senses. I shall merely point out that sensations from all spheres of the senses can be diversely combined, but always by means of consecutive reflexes. These combinations give rise to countless notions that arise in childhood, notions providing, so to speak, material for the entire subsequent psychical life. The value of this material can be summarised thus: *the child is aware, and positively so, of all the external influences surrounding its childhood; it knows them concretely, in their simplest and most ordinary forms; in other words, it knows the phenomena, as they are supplied by nature.* Finally, to show that this material already contains rudiments of higher psychical acts, I shall demonstrate that all the real substrata of the famous concept of space are already present in the child. As is known, the sole property of space is the mathematical concept of its measurability in three dimensions—length, breadth, and thickness. Everyone knows that the human eye is capable of measuring in this way. If, for example, we see before us a cube in perspective, the muscular sensations which are caused by the horizontal movement of the optical axes* crossing on the object, will correspond to the breadth of the cube; a similar movement of the optical axes up and down produces the sensation of height. Finally, the constantly changing angle of convergence of the optical axes, when we look consecutively at different points of the object lying along its depth, that is, receding from us, likewise produces muscular sensations, because the act of convergence of the optical axes is generally a muscular act. This complex process is endlessly repeated in childhood, since all objects of the external world have three dimensions. Consequently, the elements essential to the concept of space really exist at this early age.

Let me now summarise what has been said concerning the development of the child.

By means of absolutely involuntary learning of consecutive reflexes in all spheres of the senses the child acquires a multitude of more or less complete ideas of objects, i.e., elementary concrete knowledge. The latter occupies in the integral reflex exactly the same place as the sensation of fright in the involuntary movement; hence it corresponds to the activity of the central element of the reflex apparatus.

Analysis of concrete impressions of space and time is the next step in the development of the child. We shall now pass

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* Optical axes are lines and, therefore, can cross at one point only; hence, to see a line it is necessary that the point of intersection of the optical axes should be led along the entire length of the line.

to consideration of the conditions necessary for this analysis, conditions determined by the material organisation of man; we shall then see whether psychical acts of this kind with their external manifestations can be included in the category of reflexes.

But first let us answer the following important question which we owe to the reader: Does the new-born child react passively to external influences on its senses, or is it actively striving towards the external environment? In the latter case it will be necessary to disclose the nature of this striving because being added to the environmental action on the child it is bound to influence the results of this action.

Physiology has at its disposal facts which can help to elucidate this matter. From observations of adults, children and animals it is known that the first condition for maintaining the material integrity of all nerves and muscles without exception, and consequently of their functioning, is adequate exercise of these organs; for example, the optic nerve must be under the action of light, the motor nerve must be subjected to stimulation, its muscle must contract, etc. On the other hand, it is known that when the exercise of any of these organs is forcibly discontinued, a painful feeling arises in the individual, impelling him to seek for the missing exercise. It is obvious, therefore that the child does not react passively to external influences. It is equally clear that the child's striving towards the outer world is an instinctive, involuntary phenomenon; when this striving is satisfied, i.e., when it causes a certain movement in the child, it is a reflex in the full sense of the term. There is no doubt that complete dependence on this instinctive striving is responsible for the extreme mobility of the child which constantly passes from the exercise of one nerve to that of another. And it is this that ensures the all-round development of the sense organs and of movement. There is, however, another property, common to all nerves, one which prevents the child from concentrating too long on a single impression; this is fatigableness of the nerve, i.e., its property to become dulled as a result of protracted activity in one direction. These are, of course, well-known facts.

Thus, the nature of the phenomena ensuing from the action of the external environment on the child is not changed one iota by the additional influence upon them of the child's active striving. A new reflex is merely added to the series of others.

We shall pass now to the conditions necessary for the analysis of concrete impressions.

They include phenomena relating to the decomposition of the concrete impressions connected with one sensory sphere, as well as of complex impressions, for example, the visual-tactile-aural one.[15]

Let us suppose that a mosaic representing a man is placed before a child. First, the child sees the figure of the man—this is a concrete impression. Then it notices that this figure consists of head, neck, trunk, arms and legs. Later it begins to discern each little stone constituting perhaps a thousandth part of the entire picture. How does this ability to analyse and synthesise develop in the child?

An indispensable condition is, of course, the faculty of the eye simultaneously to perceive each point of the visible object separately and all the points together. This condition is ensured by the specific structure of the optical membrane and lies, therefore, in the material organisation of the eye.

The optical membrane on which the images of the observed objects are impressed and where all the nerve fibres of the optic nerve terminate can be compared with the surface of the photographic plate used for taking portraits. Just as the surface of this plate consists of a multitude of points situated close to one another but independent of one another with regard to the reception of light impressions, so the surface of the retina is a mosaic of separate areas. A ray of light cannot pass from one area into the adjacent ones. If to this we add that each area is to a degree the terminal of a separate nerve fibre, the reader will easily appreciate that since the image of an object on the retina covers a thousand areas, the eye sees this object as consisting of a thousand separate points. Moreover, the eye is able to see separately one definite point of the entire image of an object. This is attained by the uneven distribution of visual areas on the surface of the retina: near the point of intersection of the retina and of the optical axis these areas are situated close to one another; the farther from the point of intersection, the larger is the space between the areas. It is obvious, therefore, that the points of the object impressed on the retina where it is intersected by the optical axis are perceived more clearly than all the other points. As the reader is aware, this is an indispensable condition for visual attention.

A mosaic of a man is placed before the child. The latter can see the entire picture at once, but when the optical axes of its eyes are directed to one particular point, for example to the man's nose, the latter is seen best of all, the mouth and eyes less so, and the feet—the farthest removed from the nose—least of all.

Thus, it is possible to see simultaneously the whole and the part.

It is hardly necessary to dwell here on the way in which this ability, i.e., the habit of analysing concrete visual sensations, is developed; the reader undoubtedly understands that it is similar to that described by us for the development of concrete visual impressions, i.e., of a reflex acquired by frequent repetition.*

I shall but mention the importance of the analytical faculty of the eye for man's psychical life. It produces the impressions on which the concepts of the complexity of the external bodies of nature, of their divisibility and dimensions are based. Our concept of motion is also partly due to this analytical power of the eye. Motion is comprised of the displacement of the body in space as well as of the time spent on this displacement; but it is precisely this latter element that is missing in the purely visual impression produced by moving objects.

The tactile surface of the human body, like the retina of the eye, is divided into areas, each of which senses the touch of only one point of the external object. Like in the case of the retina, not all parts of the surface of the skin are equally sensitive to tactile stimulation. Sensitivity is higher on those parts of the skin where the surface of the afore-mentioned tactile areas is smaller—for example, the lips, finger-tips—and vice versa. At the given moment I have in my hand a cigarette with

* It is likewise clear that the laws of association between the components of a visual sensation and the impressions from the spheres of other senses are the same as those described for concrete sensations.

a cardboard mouth-piece. I press it to my lips and obtain the sensation of a ring. I then press it to the skin of my neck or back; I feel the contact of the object with my body, but cannot discern its form. It is obvious that in the first case the concrete sensation of a ring is due to the fact that I feel separately, so to speak, many points lying on the circumference of the ring, while in the second case the mouth-piece of the cigarette covers, perhaps, only one or two areas on the neck, and not even one on the back; hence, of all the points of the ring I am conscious of only one or two, which is not sufficient to receive the sensation of a ring.

Let us now imagine a body of a more complex form, say a star-shaped body; the lips and finger-tips will feel this shape too, i.e., all the corners of the star. It is also clear that the parts of an object which come into contact with the more sensitive points of the skin surface will be sensed more distinctly than the other parts. Hence, it is possible to distinguish separate components of a concrete sensation. If the surface of the object is rough, its projecting points exert greater pressure on the skin than the other points; here, too, we observe the inequality of separate elements of the sensation, or its decomposition.

The conditions for the analysis of concrete tactile sensations and the development of this capacity are manifestly similar to those described for visual sensations. The results are also the same, namely, concepts of the complexity, divisibility and dimensions of bodies. The sole difference is that man's visual analysis of the properties of external objects is immeasurably finer than his tactile analysis; because of this, persons with normal sight are guided by the former to a considerably greater degree than by the latter. Consequently, the results of visual analysis, too, are much finer and richer.*[16]

As is known, the analytical power of the ear** consists in its ability to distinguish separately each tone in the given com-

* The modifications of the sense of touch which produce sensations of hardness, softness, elasticity and temperature of bodies are not of a complex character and, therefore, cannot be decomposed.

** For the description of the analytical power of the ear from the physiological point of view I have used Helmholtz's famous work *The Sensations of Sound*.

bination of musical tones. In other words, the ear perceives combinations of sounds in a concrete way and decomposes these combinations into separate musical tones. It is also known that this analytical power develops as a result of exercise; that is why it is most developed in musicians. The physical conditions which ensure the analytical power of the ear can be described as follows:

In the part of the ear known as the cochlea the auditory nerve divides into separate nerve fibres; each fibre is connected with an elastic body—a resonating "key" (the nature of this connection has not yet been fully disclosed). It is believed that these keys, like the strings of a musical instrument, are tuned in a correct musical order and that a definite musical tone conforms to the vibration of each key. Man is supposed to have about 3,000 of these keys. Assuming that the ear is capable of discerning about 200 tones besides those used in music, we find that for the seven scales there are 2,800 separate keys, i.e., 400 per scale, or 33 $^1/_3$ per semitone. Clearly the ear is capable of distinguishing very minute parts of a semitone. It is also clear that the analytical capacity of the ear can go even farther than one thirtieth of a semitone. Indeed, if the pitch of the given tone falls between the tones of two neighbouring keys, both begin to vibrate; however, the vibration of the key closer to the given tone is stronger. Hence, the extreme limits of the differentiation lie between $^1/_{33}$ and $^1/_{66}$ of a semitone.

The concrete impression of a musical chord is explained, then, by the fact that all the keys which correspond to the different tones entering the chord begin to vibrate simultaneously. This also explains the concrete impression of *vowels* which are simply combinations of tones of different pitches. As to mixed sounds, noises, and consonants, the conditions for their differentiation have not yet been ascertained; it is supposed that noises, i.e., non-periodical vibrations of the air, are perceived by another part of the auditory nerve located in the extensions of the semicircular canals.

In any case aural analysis is due to the difference of the nerve fibres which receive separate elements of the acoustic impressions. Actually the mechanism here is the same as in the eye.

In one respect, however, aural sensations differ entirely from visual ones.

The following example will illustrate the point. If a certain sound, say, a musical tone, is perceived by a person, the latter quite easily determines its duration and distinguishes the sound by means of its attributes—abrupt, prolonged, very long, etc. In general, the sensation of sound is of a protracted character; this means that our hearing perceives a sound concretely, and at the same time is conscious, so to speak, of each separate moment of this sound. Hearing is an analyser of time, while the organ of sight—in the narrow sense lacks this capacity: no matter how long rays of light act on the optic nerve, the sensation of light itself is by no means protracted. For example, we cannot say in any language: "the sensation of red, white or blue was durable". If we say that a glance, like a sound, can be abrupt, protracted, very long, etc., this does not apply to the visual sensation itself, but to the muscular apparatus of the eye controlling the glance, i.e., to the convergence of the optical axes on the given object and to the adaptation of the eye which is also a muscular act.

The ability of the ear to sense the duration of a sound is an indispensable condition for the analysis of sounds in time. Actually, this analysis consists in the ability to concentrate on separate phases of the sound, which now increases and decreases in volume, now changes the periods or forms of vibrations. Singers have this ability to the highest degree. The same ability underlies, of course, our manner of speaking: we drawl one syllable to a greater, another to a lesser degree, while a third is pronounced abruptly. Even very young children can do this. Obviously, it is acquired in the same way as the capacity of articulating words in general, i.e., as a result of frequent repetition of a reflex in one and the same direction.

Taste and olfactory sensations are decomposable only to a very limited degree (various tastes and smells). As to muscular sensations, their analysis differs greatly, in the nature of the process, from the decomposition of concrete visual and aural sensations. I shall illustrate this idea by examples. *First example*: As is known, a singer knows beforehand, i.e., prior to the formation of the sound, how to arrange the voice controlling muscles in a way that produces the desired tone; he can even sing silently to himself, so to speak, any song he knows, simply by moving the corresponding muscles. Clearly this ability is based on the same analysis of muscular movements in time as in the case of sound analysis. *Another example*: When we bend the arm at the elbow, we are conscious of doing so without the help of the eyes; moreover, we are conscious of the different phases of this process, i.e., we know when the bending is slow and when it is quick; finally, we can even know—again without the help of the eyes—at what phase of the act of bending the arm has stopped moving. It is clear that man can analyse his muscular sensations not only in time, but also in space. From these examples one might conclude that in analysis of the sensations muscular sense combines the properties of eye and ear. Everyone will appreciate, however, that muscular sense itself can analyse its sensations only in time and, as we shall see shortly, even this capacity develops subject to the participation of audition and vision, as well as to frequent muscular exercise; it follows, therefore, that this is an acquired capacity. This is partly due to the fact that muscular sense as such, i.e., the sensation produced by a contracting muscle, is in itself extremely vague and weak; it is much less pronounced than any olfactory or taste sensation. Consequently, additional factors must participate in developing its specific properties, which (judging by the external nature of muscular movements), are present already in childhood. The following well-known facts show that muscular sense cannot analyse its sensations in space. Many anatomically separated muscles participate in the act of respiration, i.e., in expansion and contraction of the thoracic cavity; the concrete sensation produced by contraction of the respiratory muscles reaches our consciousness, but we are unable to single out from this combined sensation that which corresponds to each contracting muscle taken separately.

The same is true for all the movements produced not by a single muscle, but by groups of muscles. It is a different matter when the activity of one muscle separates from the activity of a number of muscles which up to the given moment had been functioning simultaneously, i.e., jointly, and when this single muscle is exercised frequently in one and the same direction;

in this case the sensation induced by contraction of this muscle must of necessity become increasingly definite in man's consciousness (let the reader imagine the act of bending one finger as separated from the act of clenching the fist). Thus, the muscular act of converging the optical axes of the eyes—one of the most frequently repeated acts—imparts to our consciousness almost the clearest of all muscular sensations. From what has been said it will not be difficult to understand the nature of the process by which an elementary muscular sensation is separated from a concrete muscular sensation, or—what is actually the same—the process of separating the activity of a single muscle from the combined activity of many; instinctive imitation by the child of what it sees and hears gives rise to this process, while exercise of the sensation due to frequent repetition is the means by which it is developed.

The examples of silent singing and of bending the arm at the elbow can be fully explained from this point of view. The first is based on a musculo-aural association, the second on a musculo-visual association. It is probably because of this that in the latter case the muscle is capable of determining spatial relationships.

Thus, thanks to the faculty of instinctive aural and visual imitation, the child, through frequent repetition of the same reflex, develops the activities of different groups of muscles. This makes its speech articulate; at the same time its external body movements become intelligent. Such, in general outline, are the results of the analysis of muscular sensations.

In conclusion, I should like to repeat that parts of concrete notions from all sensory spheres can be associated with each other or with the sum of concrete notions in exactly the same way as the latter are associated with each other (i.e., by means of habitual reflexes). The reader will appreciate that the number of psychical acts is, therefore, increased many thousand times.[17]

Having considered the conditions, process and consequences of the decomposition of visual, aural and other notions, I shall now proceed to the analysis of complex concrete notions, i.e., with their decomposition into pure components (the process of disassociation). A few examples will elucidate this question.

In the act of seeing purely visual sensations are usually associated with muscular sensations evoked by contraction of the muscles which move the eyeballs and adjust the eyes. These two sensations differ greatly. Purely visual sensations are of an absolutely objective character: although the external objects acting on the eye cause changes in the optic nerve and in the brain, i.e., in certain parts of the human organism, they are, nevertheless, always conceived by man as being outside his body. Muscular sensations, on the contrary, are of a purely subjective character—they reach man's consciousness in the shape of some kind of effort. To disunite the two sensations means to be conscious of each separately. This necessitates what is usually called attention to both. It is known, further, that attention can be concentrated easiest on the stronger sensation. Hence, for the development of disassociation it is necessary that in the complex act of seeing either the visual or the muscular sensation should be stronger. These conditions actually exist. In the daytime when we look at objects situated not too far and not too near, the visual sensation is in general incomparably stronger than the muscular one. But when the light is weak and the contours of the objects indistinct, when the object is too near to the eye, or too far from it, the reverse is observed. Thus the process of disassociation of a complex sensation also arises from the frequent repetition of the act of seeing under different conditions, this act being of a reflex nature.

The concept of the roughness of an object is of a visual and tactile character. Here, too, the process of disassociation of sensations is attained by strengthening one component at the expense of the other. Our hands encounter objects with rough surfaces both in the daytime and in darkness, and often independent of our vision. In this last case it is the vividness of the sensation that makes many people instinctively close their eyes when they want better to feel an object.

The decomposition of visual-aural associations is, of course, subordinated to the same laws. It should be pointed out that in most people, owing to the conditions under which their senses develop, aural sensations are much stronger than visual ones. The talks between mother and child, the tales which the child hears, and generally the fact that within a definite space of time it is possible to hear the names of considerably more external objects than can be actually seen, strengthen aural sensations compared with the visual. Because of this, most people in most cases think not in images, but in words, and many objects are known to man only by hearsay, i.e., partly.

When analysing associated sensations man for the first time meets his own self. Separation of all that is subjective in the sensations gives rise to self-consciousness. It is not my purpose here to trace the development of self-consciousness step by step. I shall indicate only the main factors responsible for its formation, and try to convince the reader that self-consciousness is also based on a more or less complex reflex.

The question is: How does the child learn to distinguish between the visual, aural and tactile sensations which it receives from its body, and the visual, aural and tactile sensations which it receives from the outer world, predominantly from other people?

Let us begin with vision. The child sees its hand, say, ten times a day and the hand of its mother an equal number of times.

To be able to see its hand distinctly it holds it at a definite distance from the eyes. This is accomplished by means of an acquired reflex. Thus, the child associates the visual sensation of the hand with the sensation of its movement. But to see the hand of the mother the child must perform another movement: it must, for example, come closer to the mother. As long as the different associations are few, the child, of course, cannot distinguish its own hand from its mother's. But as the number of associations increases under diverse conditions their distinguishing features become more pronounced and the mind begins to differentiate between two similar objects. This process goes still further: the child sees a toy in the hands of its mother and no less often in its own hands: the first of these sensations is simple, while the other is joined by tactile and muscular sensations. This is repeated thousands of times. The two acts begin to separate from each other, with the result that the child becomes conscious of its own hand (this phenomenon acquires a tinge of self-consciousness).

The conditions for distinguishing one's own voice from the voices of others are strongly pronounced, though both sensations are purely subjective. One's own voice is invariably accompanied by sensation in the vocal muscles, the voices of other people are not. Besides, an external sound reaches the auditory nerve mainly because of the vibration in the eardrum; faint sounds, for example, are transmitted to the auditory nerve exclusively in this way; on the other hand, transmission to the auditory nerve of the faint sound of one's own voice is largely accomplished through vibration of the bones of the skull which imparts a peculiar character to the sound. So here, too, the principal and final condition for distinguishing one's own voice from the voices of others consists in analysis of the musculo-aural association. And since the process of disassociation develops by way of repeated reflexes, the main elements of self-consciousness are the consequences of the same acts.

Add to the above the multitude of muscular sensations, always of a subjective character, which must fill the mind of the child, and you will appreciate that the psychical act of separating man's own self from the surrounding world takes place already at an early age.

The phenomena of self-consciousness include also the indistinct, obscure sensations which accompany the processes going on in the organs of the thoracic and abdominal cavities. Who, for example, has not experienced the sensations of hunger, satiety and repletion? Even insignificant disorders of the cardiac activity cause changes in man's temper; in nine cases out of ten the nervousness and irritability of women are caused by morbid states of the womb. These facts, common in human pathology, clearly point to the association of these obscure sensations with those induced by the sense organs. Unfortunately, this problem is extremely difficult to elaborate, and a satisfactory solution of it is still awaited. Its solution would be of vital importance, because the sensations we are now discussing are inherent in man, are repeated more frequently than all others, and are numbered among the most powerful factors of man's psychical development.

This capacity of the sense organs to perceive external influences in the shape of sensations, to analyse the latter in time and in space, and to combine them fully or partially into diverse groups is the sum total of the means which govern man's psychical development. But the reader acquainted with psychological literature will ask: What about the process of generalising concepts? What about the transition from lower to more generalised concepts, the combination of concepts into series, and finally, what about the products of the so-called commensuration (or comparison) of psychical acts in consciousness? The answer is that all these processes are covered by what has been said above. This can be proved by a few examples.

1) As is known, "animal" is a very general concept. Different people have different notions of the animal. Some people say that animal is what breathes; others connect this concept with freedom of movement; still others add sensitivity to movement; and finally, naturalists not so long ago believed that the simplest, and consequently typical, form of animal (*Protozoa*) is a cell —the tiny particle which constitutes the basis of all tissues of the animal body. It is obvious that although these notions are different, they have a common feature: all are notions of certain parts of the animal organism, i.e., all are products of analysis.

2) "Time" is usually regarded as a very general concept, because it implies very little reality. But it is precisely this circumstance that shows that it is based only on one part of a concrete idea. Actually, sound and muscular sensation alone give man the idea of time—and not by their entire content, but by one element only, namely, the duration of the sound and the muscular sensation. A certain object is moving before my eyes; following this object I gradually move either head or eyes, or both; in each case the visual sensation is associated with a protracted sensation of the contracting muscles; I say: "the movement is durable like a sound". In daytime man either moves himself, and thus obtains protracted sensations, or he sees the movement of other objects, which leads to the same results; finally, he hears lasting sounds (olfactory and taste sensation are also protracted). Hence, the day lasts like a sound, the year lasts like a sound, etc. If we separate the feature of durability from the concrete notions of movement of the day and of the year, we shall obtain the concept of time. Thus, here again we have the process of decomposition of the whole into its component parts.

3) The concept of "size" is usually regarded as the product of commensuration of two notions in our consciousness; this process is believed to be based on the specific faculty of comparing and drawing conclusions. The real explanation, however, is much simpler. Analysing concrete visual impressions millions of times, the eye becomes accustomed to the difference of sensations between the whole and the part in all respects and, consequently, also in respect of size. The child associates these acts with the aural sensations which identify these relations, and learns thereby to distinguish the dimensions of objects and to say which object is bigger and which is smaller. The concept of the size of the whole and of the part is subsequently cleared up by the difference in the tactile sensations which are combined with the visual. Finally, the moment comes when the difference is absolutely clear. Physiologically this moment may be described thus: The child has learned to distinguish between the number of optical areas on the retina covered by the image of an entire object and by part of it. Then, it distinguishes also the size of two separate objects impressed on the retina: the object whose image occupies a greater space on the retina is larger in size, and vice versa. The child knows two objects of the same size, and observes—once, twice, ten times, millions of times—that one of the equal objects, the one farther from the eye, always seems smaller. If the concept of the real equality of the objects is firmly embedded in the child's mind, the apparent inequality will not deceive it (for example, a four-year-old child will never confuse a playmate standing nearby with its mother who from a distance gives the impression of being the same height as the girl); in the opposite case, the child, of course, will make an error.

An adult judges the size of objects in a similar way: he feels consecutively and most distinctly (owing to frequent repetition of the process) the number of optical areas on the retina which are covered by two images. It is obvious that in this case the attention is, so to speak, focused on only one aspect of the concrete visual sensation; this, too, is analysis.

As to the combination of concepts, there is no need now to explain it with the help of examples: they combine as fragments of concrete notions.

So that the reader should be fully convinced that the aforementioned means of psychical development, despite their seeming scantiness, are themselves an inexhaustible source of this development, I shall draw his attention to the limits of human associations; every day they begin at the moment of awakening and end at the moment of falling asleep. If we suppose that the duration of this part of the day is 12 hours and that each successive phase of visual sensation lasts on the average five seconds, we shall find that every day more than 8,000 sensations enter the eye, as many enter the ear, while an immeasurably greater number are caused by muscular contraction. And every day this mass of psychical acts forms ever new combinations, the previous ones being repeated only in certain particulars.

It would be opportune now to pass on to the question of the relationship between an association, taken as a whole, and each of the external sensory stimuli of which it is composed. This, however, would be incomprehensible to the reader not yet acquainted with the so-called acts of reproduction of various sensations in human consciousness, i.e., images, sounds, tastes, etc. We shall, therefore, dwell for a while on this question. Its essence is this. Man, as is known, possesses the faculty of *thinking in images, in words and in other sensations* not directly connected with the factors that influence his sense organs at the given moment. Consequently, images and sounds are formed in his consciousness without the participation of corresponding real images and sounds from the external world. But since these images and sounds have already been seen and heard by him, the capacity to think in these images and sounds without the corresponding external substrata is known as the *capacity of reproducing sensations.*

To elucidate this phenomena, we must, apparently, deter mine the conditions whereby sounds, images and all other kinds of sensations are preserved in the nervous apparatus in a latent state during the interval between the emergence of the actual sensation and the moment of its reproduction; the conditions of the reproduction, too, must be determined.

The idea that sounds and images are preserved in the nervous apparatus in a latent state is no fancy: this preservation is, so to speak, the beginning of reproduction. Should the actual sensation end with the removal of the external substratum, there would be nothing to reproduce. The reader has probably guessed that what we have in mind here is memory, i.e., the force—still obscure to psychologists—on which all psychical development is based. Indeed, if this force were non-existent, every real sensation would not leave any trace, and we would experience its millionth repetition in exactly the same way as we did the first time; the analysis of concrete sensations with its consequences and psychical development in general would be impossible. This force, therefore, participates in every second, third and all subsequent elementary sensations right from the first minutes of man's life. That is why it should have been mentioned long ago; however, for the sake of greater coherence I deemed it advisable to present the entire subject at once. For this purpose I had first to acquaint the reader with the relationship between sensation, notion and concept from the point of view of their content. The study of memory to which we now pass will show how a pure concrete sensation is differentiated when entering into connection with similar preceding sensations; how it becomes connected subsequently with pure sensations from other spheres; and finally, how fragments of concrete sensations are interconnected. The study of the basic conditions of memory is a study of the force which links the preceding with the subsequent. Thus, memory covers all the psychical reflexes, beginning with the simplest and ending with those associated during the whole day.

What, then, is memory in its simplest, primary form?

I shall answer by citing an example. Suppose, a new-born child sees a table; this lasts for a moment, and then the infant does not see it for ten minutes; it reappears afterwards before the child's eyes, and again a more or less considerable interval follows. The child then falls asleep for the night. The next day the same thing is repeated. It would seem that every day and even every time the child should sense the same object just as it did for the first time; but the experience of centuries (with adult people who see the same objects over and over again) shows the opposite: the sensation becomes clearer and clearer. It is obvious that the nervous apparatus undergoes an increasingly profound change with each new influence encountered; between two successive influences these changes are retained by the nervous apparatus for a more or less considerable time. The capacity of retention must be inborn and, consequently, has its source in its material organisation. Are there any indications of this capacity in the physiology of the nerves?

Yes, there are. This capacity has been studied predominantly on the optic nerve, as well as on the motor nerves. Its essence can be described as follows (I speak of the optic nerve only): any stimulation of the optic nerve by light, no matter how brief, always leaves a pronounced trace which persists in the form of a real sensation for a more or less considerable time depending on the duration and strength of the actual stimulation.* Given ordinary stimulations, i.e., stimulations of average intensity and duration, the visual traces *(Nachbilder)* last for a few minutes only; in the child many hours of visual rest intervene between the last visual impression of one day and the first visual impression of the next. It would seem, therefore, that the visual traces are of no importance for the explanation of the matter. However, this conclusion, despite seeming infallibility, would be too hasty. To make the reader revise it, I shall first of all remind him that ever since the appearance of man all the way to the first half of this century, i.e., to the time when *Purkinje*[18] first published his works on visual traces, these traces, though for thousands of years they remained unnoticed, have always existed in human eyes. Hence, the absence of a clear sensation (in our case of a visual trace) by no means proves that excitation of a nerve ends when this sensation disappears. Theoretically it should persist for long, gradually and steadily diminishing. There is a belief—an essentially wrong one—that one or two drops of water cause no injury to a rock; we know that one drop of water after another can in the end wear away any rock. But, to return to the sphere of the eye, I shall give a striking example showing how defects of the eye can be corrected by influences which when considered separately are insignificant, but which produce a powerful effect when infrequently repeat-

* The reader interested in this subject can find the necessary particulars in any German textbook on physiology, in the chapter dealing with vision. The best exposition was given by Helmholtz, the greatest physiologist of this century, in his famous work on physiological optics.

ed. As is known, short-sightedness can be corrected to a degree by making the individual concentrate on objects situated at gradually increasing distances. On the other hand, it is common knowledge that when a person constantly works with small objects he becomes short-sighted. It is obvious that despite the fact that at night the eyes are at a state of rest and that during the day more or less long intervals intervene between separate acts of seeing, each act effects a change in the eyes which remains until the subsequent act begins. But who can determine the magnitude of each change?

Thus, the idea that the visual traces persist for a long time after the disappearance of the clear subjective sensation is perfectly justified.

The fact that visual sensations gradually become clearer as a result of frequent repetition in one and the same direction has been proved by direct experiments, although the nature of this perfecting of our vision still remains an enigma. It has been established, for example, that the capacity of the eye to distinguish two closely situated points or lines greatly increases (of course, to a definite limit) as a result of exercise; it is *this capacity that forms the basis of our clear vision of flat images.* It is noteworthy that the adult eye can be perfected by exercise incomparably quicker than it loses what it has acquired after the exercise is discontinued. It takes hours to learn but days to forget. These facts testify also to the capacity of the optic apparatus to preserve sensations in a latent state.

If it is possible to explain the preservation of sensations in a latent form for the duration of one night, then it should likewise be possible to explain their preservation for a number of years. Indeed, what objects does the child remember? It remembers only those which are often before its eyes; the infant soon forgets even its mother should she die. The reader may ask: How can you explain that an adult who having seen another person only once in his life, and then only briefly, recognises this person ten years later at a second meeting? It might seem that preservation of traces is out of the question here, but actually preservation takes place in this case as well. An adult, upon meeting another person even for a short time, receives from him a multitude of diverse sensations; the facial expression of the person, his features, pose, gait, manner of speaking, sound of voice, the subject of conversation, etc.—all remain in the memory for a more or less considerable time, depending on the strength of the impression; in the end, however, the traces of the impression begin to weaken. But one day another person is met, who along with other sensations induces one closely resembling the sensation produced by the first person. The latter sensation is revived in the memory, and becomes refreshed to a degree that it seems to be experienced anew. If these conditions are repeated from time to time, the traces remain. In the child, however, these conditions, even if they are present, are incomparably less pronounced.

Thus, frequent repetition of an actual sensation or of a reflex makes the sensation clearer, and because of this, it is more firmly preserved in a latent state by the nervous apparatus. The latent trace is preserved longer and longer, and the sensation is not so easily forgotten.

The perfecting of the optic apparatus derives precisely from these conditions. Indeed, if a given sensation is firmly preserved in a latent state, a very insignificant external hint is sufficient to reproduce it in the consciousness. This is proved by everyday experience and leads to the conclusion that if the optic apparatus has been exercised in one direction for a long time it can be brought into the customary state of excitation even by the most insignificant stimulus.

What has been said of concrete visual sensations is undoubtedly true of their parts, i.e., of separate sensations obtained by means of analysis. The reader will recall that fractional sensations are in their nature identical with concrete sensations.[19]

There are two other features of memory resulting from this main property of preserving sensations in a latent state: the memory of a vivid sensation is stronger than that of a weak one, and the more recent the sensation (the fresher the impression) the stronger the memory of it. These two features are easily explained from the point of view of the capacity of the optic nerve to preserve visual traces. If we examine only those phenomena which are connected with the onset of a visual trace, i.e., with the period when the trace still bears the character of an actual sensation, we shall easily see that it becomes stronger with the intensification of the external influence; the same is observed when the actual stimulation is more protracted, though its strength remains invariable. It is likewise easy to note that the trace is strongest immediately after discontinuance of the visual stimulation and that subsequently it steadily diminishes. The similarity of these phenomena is further proof that memory, being a property of the sensory apparatuses, is really due to the afore-mentioned consecutive changeability of the nerve under the influence of external stimuli.[20]

But the reader may ask: Why is a visual sensation preserved in our memory in its real form, i.e., why does the green colour remain green, a circle round, a triangle triangular, etc.? The question is easily answered. The reader already knows that the sensation of a circle, or of a triangle, emerges because different points of the circle or triangle simultaneously excite separate nerve fibres. Consequently, it suffices for the excitation to be preserved only in these fibres. And that is what actually takes place, since, according to physical laws, excitation cannot pass from an active nerve fibre to a neighbouring inactive one. As to the preservation in our memory of colours in the form of traces, no matter what physiological viewpoint is held by the reader with regard to perception of colours [21] (i.e., no matter whether he assumes the existence of different nerve fibres for the perception of different colours, or believes that the very process of nervous excitation varies according to the physical difference of the coloured rays of light), the traces are simply a prolongation of the actual optical excitation, though in a considerably weakened form.

But another question arises. As mentioned above, every day thousands of optical images fall upon the most sensitive part of the retina of the child's eye. Since all the images are preserved in the memory in a latent state, an incredible confusion may arise. How is this confusion averted? Only a general answer can be given to this question. Let us suppose that today I have seen the colour green 3,000 times, blue 500 times, and yellow 25 times. There is no doubt that till tomorrow the trace of the green colour will be strongest in my memory. However, tomorrow another colour may leave a deeper trace; at the same time the trace of the green will not remain unchanged. And although at the age of two the child is still unable clearly to distinguish between pale colours, it is already conscious of the whole rainbow, i.e., its eyes have learned to perceive even the slightest tinge of Newton's seven colours. The same can be said about contours and forms.

Thus, *in the case of purely visual concrete and fractional sensations it is the link between separate identical sensations which constitutes the trace; the trace also links the concrete image with the fraction of the image*, since these two optical phases of one process are repeated in one and the same direction.

The presence of traces in the sphere of tactile sensations is proved by the fact that when we touch a rotating cog-wheel with the finger, all the separate contacts of the teeth of the wheel with the finger merge into a continuous sensation. The direct result of the traces is also known: steady perfecting of the sense of touch, which is particularly manifest, for example, in people who lost their sight. Hence, the conditions for the development of tactile and visual memory are the same.

The existence of traces of muscular sensations cannot be proved by direct experiments (i.e., by subjective sensations),[22] but only indirectly. It should be recalled that muscular sensations always accompany the process of muscular contraction, as well as the contracted state of the muscle. If we suspend a decapitated frog vertically and pinch one of the toes of the hind leg, it will jerk the leg upwards, i.e., flex it in all joints. When the movement ends, and the leg is again hanging down, it will be seen that it remains bent at all joints, particularly, in the joint between the shank and the foot. This flexion disappears gradually in the space of half an hour, which clearly shows that the entire reflex from skin to muscle is preserved in the spinal cord as a trace.

Everybody knows the traces of taste and smell.

Aural memory alone, apparently, is an exception. Aural sensations do not leave such distinct traces as visual ones. And it is this property that explains why the ear is able to perceive the most rapid modulations of sound, i.e., to analyse them in time. However, despite the absence of perceptible traces, the auditory nerve, having undergone a certain change under the action of sound, retains this change for a more or less considerable time, just like any other body; consequently, here, too, we have conditions for the summation of repeated acoustic effects. On the other hand, aural sensations have an important advantage over all other sensations: in early childhood they are closely associated with muscular sensations arising in the chest, larynx, tongue and lips whenever we speak. Because of this, aural memory is reinforced by tactile memory. When a child thinks, it at the same time inevitably speaks. In children of five thought is expressed by speech, whisper, or at least by movement of the tongue and lips. The same thing happens very often (perhaps even always, though in varying degree) with adults. I know this at least from my own experience: my thought is often accompanied by mute speech (my mouth remaining closed and immovable), i.e., by contraction of the muscles of the tongue in the oral cavity. But whenever I want to separate a definite thought from others and fix it, I invariably whisper it. I even have the feeling that I never think in words, but always in muscular sensations which accompany my thought in the form of speech. In any case, I am unable to sing a song mentally, I always sing it with my muscles, and only then the sounds are reproduced in my memory.

Even the parrot possesses aural memory; so there is nothing extraordinary about it. Besides, it is inconceivable that the auditory nerve should not preserve acoustic traces.

The role of traces here is essentially the same as in the case of visual sensations. They connect similar preceding sensations with similar subsequent sensations; they also unite the part with the whole in time, inasmuch as the two phases of one and the same act, which underlie the analysis of a concrete aural sensation, are repeated in a definite order. It is precisely this that gives rise to the memory for words, syllables and their combinations.

Visual and purely tactile memory can be described as memory of space, while *aural and muscular memory*[23] *can be described as memory of time.*

The reader will recall that the concepts of space and time, insofar as they are based on real impressions, are fractions of concrete visual-tactile and muscular-aural sensations.

Now we shall show how associated sensations fuse into a whole.

The first condition for fusing is already known to the reader: the association is usually a continuous series of reflexes in which the end of the preceding reflex coincides in time with the beginning of the next. The second condition for strengthening the association is also known to the reader, so to speak, externally —frequent repetition of the association in one and the same direction. Let us examine the process in more detail.

As stated above, an association is a continuous series of reflexes in which the end of one reflex coincides with the beginning of the next. A reflex always ends in movement, which is invariably accompanied by muscular sensation. Consequently, an association, if regarded solely as a series of central activities, is a continuous sensation. Indeed, the middle members of every two successive reflexes, i.e., the sensations (visual, aural, etc.), are separated from each other only by movement, and the latter in its turn is accompanied by a sensation. Hence, an association is an integrated sensation like any purely visual or purely aural sensation; but it is more protracted and it is always changing. The laws of memory are, obviously, the same for associations as for purely aural concrete sensations and their fractions. Being often repeated and always leaving a trace in the form of an association, a combined sensation becomes differentiated as a whole. But its separate elements, too, are differentiated; hence, frequent repetition of the whole association in conjunction with one of its elements reveals the dependence of the former on the latter (decomposition of combined sensations into their pure elements). Because of this, *even the slightest external hint at one part of an association results in reproduction of the association as a whole.* Suppose, it is a combined visual, tactile and aural association; even the slightest external hint at one of its parts, i.e., even the weakest stimulation of the optic, auditory, or tactile nerve by a certain form or by a sound contained in this association, leads to reproduction of the entire association in consciousness. This phenomenon often occurs in the conscious life of man; it manifests itself not only in associations of sensations, i.e., in complete images, but also in combinations of the complete images, as well as concepts (fractional images) into series. An adult can distinguish between cases when external sensory excitation produces in him one corresponding sensation or notion and cases when it evokes an associated series of sensations or notions. The first occurs when an object appears before the eyes of a person absorbed in thought, bearing no relation whatever to the train of thought; although the person actually does not see the object he is vaguely conscious of its presence; this is a sensation. Given similar conditions the sensation is often so distinct that the person sees the form of the object. Finally, when an external object, so to speak, induces thought, there is an obvious reproduction of an association.

In the sphere of visual sensations there are facts which strikingly prove this law of reproduction of combined sensations. At the same time the facts clearly show the great psychological significance of the combination of sensations. These two circumstances compel me to dwell in detail on one example.

As is known, the image of an object on the retina is the smaller the farther the object is from the eye, and vice versa. It often happens that the retinal image of a small but very close object is greater than that of a large and distant object. If, for instance, we hold a finger close to the eye, it seems larger than a church in the distance. The adult, of course, is never deceived by this phenomenon: he knows from experience that the church is taller by far than he himself; so he draws *correct conclusions* concerning the dimensions of the objects which he compares. It might seem that the concept of the size of objects situated at varying distances from the eye is the result of thinking; however, the following simple experiment proves the opposite: in a dark room lit by one candle we close both eyes for a few moments; then we open one of them, look attentively at the candle for two or three seconds and close it again. The image of the candle will remain for some time in the dark field of vision; this is a visual trace. Now, while this trace still persists let us try to imagine—without opening our eyes—that we are looking right in front of us; in this case the after-image becomes smaller. If we imagine that we are looking into the distance, the image becomes enlarged. The explanation is this. The concept of the dimensions of an object seen with one eye is based on the actual size of its image on the retina and on the degree of tension of the muscles which adjust the eye for distant vision. If the second factor changes, while the first remains invariable (as in our example), the impression which results from the combination of both sensations (the visual-muscular association) also changes. In life the visual-muscular association mentioned in our example always follows the following pattern: when two objects situated at different distances from the eyes produce on the retina images of the same size, the eyes must be adjusted to distant vision to see the farther and larger object, and to near vision to see the closer and smaller object. That is why the association (concept of size) in the above example is reproduced in the form of a larger object when we accommodate our eyes to distant vision and in the form of a smaller object when we accommodate them to near vision.

Here is another interesting example from the sphere of cutaneous sensations.

It is common knowledge that cold often causes "goose-flesh" contraction of special small muscles in the skin. This phenomenon, obviously, is a reflex complicated by the conscious sensation of cold and, in this sense, it is absolutely involuntary; however, I know a gentleman who can get goose-flesh even in a warm room, merely by imagining that he feels cold. In this remarkable case imagination produces the same effect as the actual sensory stimulation.

What, then, is the act of reproducing psychical formations? Essentially it is a process of excitation of the central nervous mechanisms as real as in the case of any acute psychical formation caused by the action of an external agent on the sense organs. And I maintain that from the point of view of the processes taking place in the nervous mechanisms it is not important whether I see a real man before me or simply recall him. The only difference is that among the numerous sensations evoked in me directly by the man, the visual sensation is particularly clear and sharp, because it is constantly supported by real visual stimulation (but if the man relates extremely curious things my aural sensation is stronger than the visual; the reasons for this will be discussed in the section devoted to emotions). When I recall the man, the first stimulus for his appearance in my memory comes usually from the influence exerted on me at the given moment by a certain external agent which, among many others, was acting on me the moment I saw the man. This stimulus evokes the whole complex of sensations produced in me by the man and preserved in the form of traces; his figure, words, expression of his face, movements of his hands, etc., begin to flash in my consciousness one after another. It is often difficult to determine which of the images is strongest, because my attention does not remain fixed on any one of them for long. However, everyone knows that a man with an arresting countenance and an ordinary voice is better remembered in images than in words, and vice versa. This is due to the fact that the intensity of latent traces wholly depends on the strength of the actual impressions.

I repeat: *from the standpoint of the process, there is not the slightest difference between an actual impression with its consequences and the memory of this impression.* Essentially, this is one and the same psychical reflex with an identical psychical content, but evoked by different stimuli. *I see a man* because his image is actually focused on the retina of my eye, and *I remember him* because impressed on my mind is the image of the door at which he stood.

By now the reader will have an idea of the importance of frequent repetition of one and the same act for psychical development. Repetition is the mother of learning, i.e., of a better differentiation of all psychical formations.

The laws of latent traces, applied to the process of acquiring muscular movements by learning, easily explain one of the phenomena of the act of learning which we call the instinctive "aping" of the child under the control of audition and sight. For the sake of clarity I shall use an example showing the process by which the child learns the name of a certain object. The reader knows that in the child there are among other reflexes also reflexes from eye and ear to the voice: the child screams at the sight of an object or when it hears something. In the first case the latent traces retain a visual-muscular-aural association, and in the second case an aural-muscular-aural sensation. According to the law of differentation of sensations, the acoustic components in the second case become differentiated most rapidly when they are similar. And that is what actually takes place since such similarity is present. The child hears the mooing of cows and screams. But in this scream, for all that is seems absolutely meaningless, and consequently in the latent traces left by it, there are acoustic elements, similar to the mooing of the cow. As a result of repetition, the aural-muscular-aural association changes so that the identical acoustic elements become increasingly clearer; at the same time the position of the vocal apparatus, which is necessary to reproduce the similar acoustic elements, becomes more and more fixed. Hence, the differentiation of an association is *most rapid* when its acoustic elements are similar.

It is natural that at the sight of a cow the child reproduces mooing sounds, i.e., imitates what it hears and at the same time learns the names of objects. The names of inanimate soundless objects are learned by the child in the same way. The mother or the nurse associate in the child's mind the given visual image with a sound, and this association is renewed in the child hundreds and thousands of times, until the acoustic components become fully differentiated, i.e., until the child is able to pronounce the name of the given object.

No examples are needed to illustrate the child's visual imitation, or its consequence—the process of learning muscular movements. I shall merely say here that this is wholly a matter of differentiation of the visual components of the child's visual-muscular-visual association.

Thus the theory of latent traces has, presumably, clarified those aspects of psychical development which previously remained obscure to the reader, namely, the differentiation of sensations, notions, etc., as a result of repetition, and the process of learning muscular movements.

Lastly, I would ask the reader to pay attention to the following aspect of reproduction of impressions.

As already stated, any complete psychical reflex ends in a muscular movement which is invariably accompanied by sensations (muscular); consequently, the trace of a complete reflex, which is a latent sensation, includes the beginning, continuation and the end of the act. It follows from this that the act becomes differentiated in man's consciousness as a whole. At the same time, due to the analysis of the associated sensations, notions, etc., separate moments of the act—its beginning, duration and end—are likewise differentiated; hence, man becomes conscious of the complexity of the act, of the dependence of movements on notions. The relationships between the different elements of the psychical reflex will be discussed below, when we analyse the act of thinking.

And now let me summarise what has been said in the following general formula:

All psychical acts without exception, if they are not complicated by elements of emotion (we shall dwell on these elements later) *develop by way of reflex. Hence, all conscious movements resulting from these acts and usually described as voluntary, are reflex movements in the strict sense of the term.*

Thus, the question whether voluntary movements are based on stimulation of sensory nerves has been answered in the affirmative. It is also clear why in voluntary movements this sensory stimulation often remains unnoticed, or at least cannot be determined.

Although the reasons for this are many, they can be reduced to the following:

1) Often, if not always, a distinct association, for example, a visual-aural one, is supplemented by a vague muscular, olfactory, or some other association. In this case, because of the vividness of the first association, the second is hardly noticeable, or it remains unnoticed altogether. But it exists, and as soon as it flashes in our consciousness even for a moment, it evokes the visual-aural association. Here is an example. In the daytime I am busy with physiology, but at night when I go to bed I think of politics and it happens, of course, that sometimes my thoughts roam to the Emperor of China. So an acoustic trace becomes associated with the various sensations evoked in me by the state of lying in bed, i.e., with muscular, tactile, thermal and other sensations. Sometimes, being tired or having nothing to do, I lie down in the daytime and all of a sudden the thought of the Emperor of China comes into my mind. It is usually said that thoughts like this have no particular cause; actually, however, the thought of the Emperor of China was engendered by the sensation of lying down. And now that I have cited this example,

it will come to mind even more frequently, because it has become associated with more vivid notions.[24]

2) A series of logically interconnected notions can become associated with another notion which bears no relation whatever to them. In this case, it seems strange to deduce a series of thoughts from this notion; actually, however, it is this notion that engenders such a series.

3) Sometimes a chain of associated notions persists for long in our consciousness. As already stated, its maximum duration is from the moment we wake up in the morning till the moment we fall asleep at night. In such cases, it is extremely difficult to recall precisely what induced the series.

However, in most cases, if we attentively observe ourselves, it is possible to establish the external influence which engendered the given series.

§ 12. Now I shall pass to the second question: Does the mechanism of inhibition, already known to us from the study of reflexes, play any role in originating voluntary movements? This is a natural question, seeing that we have identified the process of voluntary movements with the development of reflexes.

Are there any phenomena in man's conscious life which show that movements are inhibited? These phenomena are so numerous and so pronounced that it is because of them that all movements effected with full consciousness are called voluntary movements. On what is the usual concept of these movements based? It is based on the fact that man, influenced by one and the same external and moral conditions, can perform a definite series of movements, exhibit no movement at all, or, finally, can perform movements of an altogether reverse nature. As is known, people of strong will can suppress the most irresistible, seemingly involuntary movements; for example, one man screams and struggles when suffering acute physical pain, another endures it silently without making the slightest movement, while a third performs movements which are utterly incompatible with pain, for example, he jokes and laughs.

Consequently in conscious life there are cases of inhibition both of movements generally regarded as involuntary, and of those known as voluntary. Since, however, voluntary movements develop in accordance with the basic laws of reflexes, we may, naturally, assume that the mechanism of inhibition in both cases is the same.

In chapter one of this book we considered involuntary movements arising when sensory excitation is anticipated, and pointed out that such phenomena can best be explained by the intervention of a new element which inhibits the activity of the reflex apparatus. We also referred to experiments which show that there is no doubt whatever about the existence of these mechanisms in the brain of the frog, and that their presence in the human brain is highly probable.

Now we must establish whether this hypothesis is also true for voluntary movements.

Let us accept this hypothesis and assume that there are mechanisms in the human brain which inhibit muscular movements. But the reader may ask: Why is the activity of these mechanisms manifested so unevenly in different individuals? If inhibition of movements had an organic origin one would think that it should not vary in different people to the degree that it does (a weak nervous woman and an extreme stoic); moreover, inhibition would be present also in the child. As a matter of fact it exists in all cases, but man must learn to control the inhibition of movements just as he learns to perform the movements themselves. Nobody, for example, doubts that a new-born child already possesses all the nervous centres which subsequently control the acts of walking, speech, etc.; nevertheless the child must learn to perform these acts.

Let us now see how the child's ability to inhibit movements, or, strictly speaking, to eliminate the last member of a reflex, is acquired by learning.

Childhood is generally characterised by extremely extensive reflex movements arising in response to relatively weak (from the adult point of view) external sensory stimulations. For example, reflexes from ear and eye spread to almost all the muscles of the body. The time comes, however, when the movements, so to speak, become grouped. One or two entire groups of muscles separate from the mass of other muscles which have functioned in a disorderly manner; having become more limited, the movements acquire a definite character. It is in this limiting process that the inhibitory mechanisms take part. For the sake of simplicity, let us examine the transition from the simultaneous flexion of all the fingers of the hand to the separate flexion of one finger. Assuming that the simultaneous flexion of all fingers is due to certain inborn properties of the child's make-up (which is really so), it is obvious that one finger can be moved separately only if the movement of the other fingers is inhibited. There is no other explanation. But what causes this inhibition? It can be supposed that the flexion of the fingers is prevented by the functioning of the muscles which act in opposition to the flexors, i.e., contraction of the extensors; at first sight this supposition seems highly probable. To keep the other four fingers in a state of immobility, it suffices during the flexion of one finger for contraction of the extensors of the other four to prevail—even very slightly—over that of their flexors. True, this preponderance should be accompanied by certain muscular sensations, because the state of immobility is still the result of the antagonism between two sets of muscles; but the sensation should be very weak and for this reason may remain unnoticed in the presence of a distinct muscular sensation obtained from bending the finger. The matter can be explained, apparently, without the participation of special mechanisms inhibiting movements, and boils down to the functioning of antagonistic muscles. But this explanation cannot be fully accepted. Imagine that the simultaneous flexion of all fingers is engendered by a very powerful cause. In this case, the flexion of one finger must be accompanied by a very strong desire to bend the other four; hence, the latter can remain in a state of immobility only when the activity of the antagonistic muscles is most pronounced. In this case the flexion of one finger would be accompanied by an extremely acute muscular sensation in all the others. But in reality this does not occur. A person of ideally strong will can endure pain with composure, i.e., without muscular contraction.

So, while not denying in the least that inhibition of movements can be caused by the contraction of antagonistic muscles, and even granting that this frequently takes place in the process of preventing conscious movements, we must, however, admit the functioning, in some cases, of a mechanism acting on the reflex movement in the same way as the vagus nerve acts on the heart, i.e., an activity which paralyses the muscles.

From this it follows that if a conscious psychical act is not accompanied by any external manifestation, it still remains a reflex. And if we admit that in all these cases the prevention of movements is due to the activity of antagonistic muscles, then the end of the act must be a purely muscular movement; but if we accept the other explanation, the end of the reflex must be an act fully equivalent to the excitation of the muscular apparatus, i.e., the motor nerve and its muscle.

As to the development of capacity to inhibit the end of reflexes, the first case fully accords in this respect with the development of grouped muscular movements in general, and the vast difference in the external manifestation of both phenomena (performance of a movement and its inhibition) is explained by participation of different muscles in the movement. Hence the instinctive imitation of the child is the beginning of capacity to prevent movements; muscular sensation and its analysis are the guiding factors, and frequent repetition is the means by which capacity is acquired. When the child learnt to control its muscles, i.e., when it is able to walk and talk (and, consequently, to understand speech) the capacity to inhibit movements is further perfected through the development in the child's mind of associated concepts of the following kind: "Don't do this, don't do that, if you do, this or that may happen!" For the sake of greater edification these admonitions are often associated with painful physical sensations, which greatly affect the future of the child; with this system of education the morality of the motive by which the child is guided becomes overshadowed by the stronger sensation of fear, and the grievous morale of frightened people develops in the world.

The development of the capacity to paralyse movements (the reader should not forget that with regard to man this capacity is merely a hypothesis) is extremely obscure, because the only guiding factor is the sensation which accompanies the inactive state of the muscles. The reader will get a better idea of this by performing the following experiment on himself: after an exhaling movement delay for some time the subsequent involuntary movement of inhaling. During the first few seconds there will be no distinct feeling (one will be but indirectly conscious of the fact that the muscles are in a state of immobility); afterwards a certain feeling will set in—but not in the muscles —which will impel inhalation.

This example undoubtedly is one of those in which the inhibition of movements takes place without any active contraction of the muscles; it can be explained, therefore, only by the activity of a mechanism which paralyses the involuntary inhaling movements. From this example the reader will gather that the muscular sensations accompanying the inhibition of movements are really weak. The fact that teachers cannot develop in their pupils the capacity to paralyse the external manifestations of their psychical activity must be attributed precisely to this circumstance. This also explains why this capacity is rarely encountered in man and why persons possessing it are, to a degree, regarded as freaks of nature. As to other means of developing this capacity, here, as in the case of learning any kind of muscular movement, frequent repetition is of decisive significance. It is said that the present Emperor of France is able to conceal his internal emotions to the point of external impassivity; it is also said that he has achieved this by a tireless study of his own face in the mirror. I have obtained even more convincing proof of what has been said above by observing dogs. But to make it clear to the reader, I consider it necessary first to say a few words about the way in which the cerebral mechanisms that inhibit reflexes are excited and aroused to activity. In frogs, where the presence of these mechanisms in the brain has been proved beyond all question, they become excited, i.e., they inhibit reflexes, every time the sensory nerves are subjected to strong stimulation. Probably the same occurs when stimulation of the sensory nerves is weak, but in this case the effect is so insignificant that it cannot be detected by our crude methods. In the frog, then, the mechanisms that inhibit movements become excited in a reflex way.

Granting the presence of similar mechanisms in man as logical necessity, we are bound to admit that they are excited by means of reflexes. From this it follows in general that if in the course of life a man or an animal is subjected frequently to sharp external influences acting upon the sense organs, there is the likelihood that the man or the animal will greatly develop the capacity to resist these influences.

It has been said that people living a grim life of toil endure acute pain with absolute composure, without complicating the process by emotion. From the point of view of what has been said above, this "crudeness" of the nerves is quite explainable. It is also clear that the conditions in which the children of the so-called cultured classes are brought up preclude this "crudeness" of nerves in adults too.

The following example will prove this to the hilt. Being a physiologist, I am, unfortunately, compelled to experiment with animals; in the course of these experiments I have seen real heroes among plebeian dogs, i.e., dogs that live anywhere and eat anything; even the most terrible pain is endured with barely a moan. Nothing of the kind is observed in pet dogs, especially in lapdogs. And since dogs cannot, of course, manifest any emotion, this speaks for itself.

Thus, *man not only learns to group his movements through the frequent repetition of associated reflexes, he, at the same time, acquires (also by means of reflexes) capacity to inhibit them.* That is why psychical activity in the multitude of phenomena remains, so to speak, without external manifestation, i.e., in the form of thoughts, intentions, wishes, etc.

I shall now show the reader the first and most important result of man's capacity to inhibit the last member of a reflex. This can be summarised as *the ability to think, meditate, and reason.* What, actually, is the process of thinking? It is the series of interconnected notions and concepts which exists in man's consciousness at a given time and which is not expressed in external manifestations resulting from these psychical acts. But a psychical act, as the reader knows, cannot appear in consciousness without an external sensory stimulation. Consequently, thought is also subordinated to this law. It manifests, therefore, the beginning of a reflex and its continuation; only the end of the reflex, i.e., movement, is apparently absent.

A thought is the first two-thirds of a psychical reflex. This can be best explained by means of an example.

At the present moment I am thinking silently, without performing the slightest movement: "The bell which is before me on the table has the shape of a bottle; it is hard and cold to the touch and if I shake it, it will ring." This is a thought, just like any other thought. Let us examine the main phases in the development of this thought from childhood.

When I was about a year old I used to react as follows to this bell: looking at it or simultaneously looking and taking hold of it, or simply taking it without looking, I moved my hands and feet, and when it rang I was so pleased that I began to move my hands and feet even more vigorously. The psychical aspect of the phenomenon as a whole consisted of an associated notion in which the visual, aural, tactile, muscular and, lastly, thermal sensations merged.

Two years later I stood on my feet, held the bell in my hand, shook it, smiled and said: "ding-ding". In this case, not all the muscles of my body, but only the muscles of speech were involved in the reflex. At this stage the psychical side of the act is greatly advanced: the child is able to recognise the bell by shape, sound, or touch; it even knows the sensation of cold. All this is the result of analysis.

The child's development continues: its capacity to inhibit reflexes becomes more pronounced, but its interest in the bell steadily declines (we have already said that a nerve becomes fatigued and dulled when too frequently exercised in one and the same direction). Finally, the time comes when the child rings the bell even without a smile. At this stage it is able to express in words the thought mentioned by me at the beginning.

Since the thought is expressed in words, the reflex is confined to the muscles of speech only.

Already at this age the child can, by means of muscular-aural disassociation, separate in its consciousness the aural sensations of words which constitute a thought from the muscular speech movements expressing this thought. Moreover, it is already capable of inhibiting speech. It is obvious that even a child can think quietly about a bell.

So when it is said that a thought is the reproduction of reality, i.e., of real past impressions, this is true not only for the development of thinking from childhood, but also for every thought which is repeated in one and the same form even for the millionth time, because the reader already knows that from the point of view of the nature of the process, the acts of a real impression and of its reproduction are identical.

I shall now dwell briefly on the properties of thought, so that the reader will have no difficulty in understanding me later on, when we discuss the illusions of self-consciousness.

Thought, by its nature, is highly subjective. The reason for this will be easily appreciated if we recall the history of its development. Thought is based on sensations from all spheres of senses which are themselves half subjective; even the visual and tactile sensations, which are of a purely objective character, at the moment of their emergence, can become completely subjective in thought, for most people think of tactile and visual images in words, i.e., by means of purely subjective aural sensations. Lastly, irrespective of the fact that in thought objective sensations become subjective (by means of visual-tactile-aural disassociation), our visual and tactile sensations, even when we think in images, as a rule have no real vividness in thought, i.e., the images are never as vivid in thought as they are in reality. This, of course, is due to the fact that the visual and tactile sensations are associated with others; consequently, there is no reason why in thought our attention should be concentrated on the visual and not on the aural sensation. But when our eyes or hands encounter a real external object, there is cause for concentrating attention precisely in this direction. It follows, therefore, that thinking in images does not interfere with the subjective nature of our thoughts.

Now the reader, being aware of the properties of thought, will understand how man learns to separate thoughts from the external acts which follow them. Indeed, in any man affected by sensory stimulation thought is sometimes directly followed by action; at other times movement is inhibited and the act seems to end with the thought; at still other times thought again leads to action, but the latter is different from that in the first case. It is clear that thought, as something concrete, must separate from action which also appears in a concrete form. Since the succession of two acts is usually regarded as an indication of their causal relationship (*post hoc ergo propter hoc*), *thought is generally accepted as the cause of action.*[25] When the external influence, i.e., the sensory stimulus, remains unnoticed—

which occurs very often—*thought is even accepted as the initial cause of action.* Add to this the strongly pronounced subjective nature of thought, and you will realise how firmly man must believe in the voice of self-consciousness when it tells him such things. But actually this is the greatest of falsehoods: *the initial cause of any action always lies in external sensory stimulation,* because without this thought is inconceivable.

The seeming ability of one and the same person to express a definite thought by different external actions leads self-consciousness into a new sphere of errors. Influenced by a certain thought a person, as we are used to say, often deliberates on the mode of his action, and finally chooses one of its many possible forms. This means that influenced by definite external and internal conditions, he manifests the intermediate member of a psychical reflex (for the sake of brevity I shall use this term for any integral act of conscious life); and to this intermediate member is added—also in the form of thought—the image of a certain end of the reflex. If this intermediate member had several ends (seeing that the reflex developed in different external conditions) it would only be natural for them to appear in imagination one after another. Later we shall discuss the inevitable motives that determine the so-called choice of one or another end of the reflex.

Thus, we have replied in the affirmative also to our second question. *There are many psychical reflexes whose last member, i.e., movement, is inhibited.*

§ 13. I now pass to the third and last part of our investigation of the acts of conscious life, namely, to those psychical reflexes which have an intensified end. The phenomena belonging to these reflexes embrace the entire sphere of emotion.

Our task will be merely to show that emotions are, in origin, intensified reflexes.

As pointed out in the chapter on involuntary movements, emotion originates in the elementary sensual pleasures of the child. The sight of a brightly coloured object, the sound of a bell, etc., produce excessively irradiated reflex movements. But the state of excitement evoked by a definite object is not durable; at the age of three or four the child is no longer amused by objects, say, of a red colour; but it likes brightly coloured pictures and gaily dressed dolls, it listens with keen interest to stories concerning every kind of brilliance. It is obvious that, with the development of concrete notions, the pleasure obtained by the child from their separate properties merges, so to say, with the notion as a whole, and the child begins to enjoy complete images, shapes, and sounds. Thus, the whole impression acquires a highly emotional character. The attachment of the child to mother or nurse is of the same origin: the images of mother and nurse are always associated in the child with pleasure in all spheres of the senses, predominantly, of course, with the pleasure of eating. So it is not without reason that children are called egoists.

Desires arise in the child along with the development of emotional psychical formations. For example, the child likes the image of a burning candle, and has often seen how a candle is lighted with a match. A series of images and sounds preceding the lighting of the candle become associated in the child's mind. Now let us suppose that the child is absolutely quiet; suddenly it hears somebody strike a match, and its immediate reaction is extreme delight, it cries out and tries to reach the candle, etc. It is clear that the sound of the match inevitably evokes in the child's mind a pleasant sensation; hence its joy. But should the candle not be lighted, the child becomes restless and begins to cry. It is said, that this is the result of unsatisfied desire.

Here is another example. Suppose that tonight, when the child was being put to bed it was told a story that delighted it; this means that emotional aural sensations were associated in its mind with the sensations of lying in bed. There is no doubt that tomorrow at bedtime it will ask for another story, and will whimper until the story is told.

Obviously the recollection of pleasure, being of an emotional character, differs from actual pleasure just as hunger, thirst, and sensuality in the shape of desire differ from the pleasure of eating, drinking, etc. Generally speaking, desire can be compared with the feeling of hunger both from the psychological and physiological points of view. The only difference between visual desire and hunger, thirst, or sensuality, is that in the case of visual desire the oppressive sensation common to all desires is associated with an image; in the case of an aural desire it is associated with the notion of sounds, etc. The oppressive sensation itself derives from the specific and so far unexplained organisation of the nervous mechanisms, under which the insufficient exercise of these mechanisms always produces a feeling of depression.

The reader will now have an idea of the mechanism of caprice as well. Any desire is as oppressive as hunger and thirst and, if not satisfied for a long time, evokes a similar reaction. When the child is hungry or thirsty it is usually restless and cries; consequently, the same thing is bound to occur in the case of unsatisfied desire.

In the organisation of the nervous mechanisms there is another condition for the development of emotion: the more frequently these mechanisms function, the greater and more urgent becomes the necessity for them to act (there are, however, limits to the frequency and intensity of repetition). Three-quarters of all Europeans are immoderate in food and drink, they thereby intensify their feeling of hunger and thirst and make its emergence more frequent; the same is true of people who are immoderate in sexual pleasures. This law, when applied to pleasures in the sphere of higher senses, i.e., vision and audition, is easily explained. The more frequently an emotional psychical reflex is repeated, the greater the number of extraneous images and notions with which it is associated and, consequently, the easier the reproduction of the emotional reflex in the form of thought, i.e., of desire.

From this it follows that the development of emotion is subject to the same laws as, for example, the development of images from sensations. It originates in the instinctive craving for sensual pleasure, while frequent repetition of the pleasure or of the psychical reflex, which is the same, is the means by which it is developed.

But there is a difference between these two acts. When a reflex is frequently repeated in one and the same direction, its psychical element (sensation, notion, etc.), apart from the emotional element by which it is accompanied, becomes clearer (through association and analysis); emotion, on the contrary, often disappears. The child becomes tired of its toy. Things that delighted it at the age of two, leave it indifferent at five; as to the adult, he is indifferent to the amusements and joys of children altogether. The following conclusion is usually drawn from these facts: Man is so constructed that a frequently repeated impression, no matter how pleasant, begins to pall him; many people even go farther and say that our nerves are so constructed that they are fatigued by a pleasant impression, if it is frequently repeated.

Here are the only physiological facts, which confirm this. If light of a certain colour, for example red light, acts on the eye for long, the sensation of red becomes dulled: what previously seemed very bright gradually begins to seem paler. A musical tone irritates the ear if it sounds too long. On the contrary, the ear can listen with pleasure for a long time to modulations. The same is true of the eye: we can look at varying colours longer and with greater pleasure than at one particular colour. In what way do these facts come within the phenomena that we are now considering? Every invariable external influence acting on the child must in its consciousness pass through all phases of gradual fading. When this influence is repeated frequently, the difference between vividness of its beginning and paleness of its ending (i.e., between emotion and impassivity) becomes more and more distinct in consciousness. The beginning remains emotional in the positive sense, while the end acquires a more and more negative-emotional character. These two sensations, always accompanying each other, must of necessity be balanced. Numerous facts speak in favour of this explanation. It is possible, for example, to like a certain dish—say, roast grouse—and to eat it with pleasure; but everyone knows that the first grouse, eaten after a long period of abstention from this dish, tastes incomparably better than the tenth; if you treat yourself to grouse every day for months, the time will come when you will look at it with aversion. Clearly this feeling is of a negative-emotional character compared with the feeling that accompanies the eating of grouse for the first time; in the foregoing example this steadily increasing negative feeling first counterbalances the positive-emotional feeling and then overpowers it.

Another very important factor plays a definite role in the disappearance of emotion from many psychical reflexes. When a reflex of an emotional character is repeated many times, a decomposition of the concrete impression finally takes place. After the first transports of delight evoked by the appearance of a new doll the child begins to analyse it. This process is repeated, and the products of analysis become ever clearer in the child's consciousness; in other words, they are reproduced with increasing ease whenever opportunity is present. Thus, the delight of the concrete impression gives way to the clarity of placid consideration. By this I do not mean that analysis inevitably kills pleasure: parts are often no less pleasant than the whole, and the analyst does not lose the capacity of feeling concretely.

Replacement of an old image by a similar new one facilitates the disappearance of emotion from a psychical reflex. Let us suppose that a child has only one rather poor toy and has never seen a better one. This toy gives pleasure for quite a long time—of course, with intervals. Now let us suppose that this child catches a glimpse of another toy—one that is possibly no better than its own. The image of the new toy will be firmly associated in the child's mind with the impression of the old one, and the latter will no longer yield full satisfaction. Everything new, like everything unexpected, affects the child strongly, just as it does the adult. Surprise is related to fear. Pleasure, aversion, and even fear often begin with surprise. The infant just beginning to see, hear and feel is naturally surprised at everything.

Lastly, no matter how strong it may be, the emotion of a psychical reflex is gradually extinguished with the disappearance of the external influence which induced it. This is the reverse of the law according to which frequent repetition of an emotional psychical reflex both in reality and in thought strengthens emotion to a degree. The nature of this process is also quite clear. Just as any image, when reproduced in thought, is paler than it is in reality, i.e., when the respective object is actually encountered, actual emotion is much stronger than that which is imagined. For this reason alone emotion is bound to diminish with the removal of the real substratum. Moreover, with the weakening of emotion the reproduction of an emotional image in thought inevitably becomes less and less frequent, this being the second factor which accelerates the disappearance of emotion. And an emotional image reproduced in thought is associated with oppressive sensations of longing which impart to the entire psychical act a specific, though still emotional, character, but in the opposite direction.

Such, then, is the beginning and such are the conditions for the development, as well as for the disappearance, of emotion in the child. I should like now to summarise what I have said.

At the beginning of human life all psychical reflexes without exception are of an emotional character, i.e., they have intensified ends. However, little by little the sphere of emotion narrows, and pale and monotonous images gradually give way to brighter and more mobile ones. This process is based on the analysis of similar concrete sensations which, however, may be more or less vivid and more or less mobile. Frequent repetition of an emotional impression will, to a degree, strengthen the emotion, because reproduction of the emotional notion and of its result, i.e., of desire, becomes more and more frequent. In social life emotion is measured by its strength or depth and vividness. The strength or depth of emotion just like the clarity of a notion derives from frequent repetition of the reflex. As to the vividness of emotion, it is supported by the mobility of the impression, or by the sum of pleasures possible at the given time. In an emotional psychical act desire is of the same importance as thought in an ordinary psychical act—being the first two-thirds of the reflex. The oppressive side of desire is in its turn a source of emotion, though differently expressed compared with pleasure. Negative emotion is subject to the same laws as positive emotion: here, too, the strength is determined by frequency of repetition, while the vividness depends on acuity of the oppressive desire. Fortunately for mankind, human nature does not favour a steady intensification of negative emotions; being the mental reproduction of an emotional act, desire cannot be as vivid as the latter; at the second reproduction it becomes less vivid, at the third still less, etc. Consequently, pronounced development of negative emotion can be maintained for a long time only by a constant actual deficiency of sensual pleasures, or, as it is often said, by constant failures in life. Indeed, one can get accustomed to cold, hunger and even to the dark, silent prison.

It follows, then, that emotion in children is generally characterised *by high mobility.*

With the development of the child, its concepts, or to be more precise, the images connected with them, become emotional. This can be best illustrated by the following example. Under the present-day method of education the child's emotion switches from toys to heroes, strength, courage and similar qualities. It is obvious that this emotion is induced mainly by the images of swords, spears, armour, plumed helmets, and horses; in short, the child's mind is again full of glowing pictures, but they are now much clearer and more varied. This change in the child is inevitable, due to its natural striving for light, brilliance and noise, and also to the present-day methods of education. We shall see later that the change is, in some respects, a positive factor. But owing to superfluous impregnation of the sense organs with images of knights the emotion of very many people is forever concentrated mainly on outward brilliance. This might have been the ideal thing in the Middle Ages, but in our life, with its toil and lack of brilliance, such people are out of place.

And yet the child's attraction to strength, courage and valour is in one respect a positive factor. By this time the child has already separated its personality from the external world and, unconsciously, of course, loves itself very much, or to be more correct, loves itself in pleasure. (Imagine an adult person who always experiences only unpleasant sensations and never pleasant ones; obviously he will be, so to speak, a burden to himself, i.e., will never love himself.) It is no wonder, therefore, that the child girds itself with a sabre, puts on a helmet and rides a stick. It associates its personality with the heroes who pass through its mind and, of course, with all their qualities—at first purely external ones. With the passage of time, due to repeated aural reflexes (stories), the child's concept of the knight assumes more and more knightly properties. If into the composition of the knight an aversion to vice is introduced, the child, while associating itself with the knight, will despise vice, in its own way, of course, i.e., according to its concept of vice. If the knight helps the weak against the strong, the child becomes a Don Quixote: it will tremble at the thought of the defenceless weak.

Associating itself with an image, the child begins by loving all the properties of this image; subsequently, as a result of analysis it loves only these properties. This is what determines the moral side of man.

Love of truth, generosity, compassion, unselfishness, as well as hatred of all the opposite features, develop, of course, in the same way, i.e., by means of frequent repetition in man's consciousness of emotional images (no matter whether visual or aural), in which the above-mentioned properties are vividly manifested. It is no wonder, therefore, that a youth of eighteen, who ardently loves truth and is not impelled in the opposite direction by motives that develop in most people only at a mature age, is ready to endure torments for this truth. He knows that his ideal knights also suffered for truth, and he cannot but be a knight, since he has been one from the age of five to eighteen.

If the reader has attentively followed this example, he will easily see that our emotional worship of virtues and our aversion to vice are based on nothing else but an extremely extensive series of psychical reflexes: emotion is first directed to the bright colour of a certain object, then it switches to the bright mantle of a knight as shown in a picture, then to oneself mentally arrayed in knightly garments; emotion turns from concrete impressions to particular notions, i.e., to the virtues of the knight, or to concrete images in new forms and, finally, leaving the covering of a knight, turns to similar properties in the peasant, soldier, official, or general. It should now be clear to the reader that one may remain a knight even at a mature age. Naturally, by this time emotion has diminished, but it is replaced by what is usually called deep conviction. People of this type, given favourable conditions, develop into the noble characters mentioned at the beginning of this chapter. In their activity they are guided exclusively by lofty moral motives—by truth, love of man, and tolerance for his frailties; they remain true to their convictions despite all natural instincts, because the latter fade before the brightness of the pleasure which the knight derives from truth and love of man. These people cannot, of course, change: their activity is the inevitable result of their development.[26] And there is much consolation in this thought:

without it belief in the durability of virtue would be impossible.

In summing up this survey devoted to emotions, I shall cite one more example—the love of man for woman; this is especially important in view of the extremely widespread perverted concepts of this problem.

There is an instinctive side to the love of man for woman—sexual attraction. This is the beginning of love, because it arises in the boy only when his sex organs become mature. I shall not attempt to answer the question whether the boy involuntarily associates his first sexual sensations with the image of a woman, or whether this association is prepared by knowledge already acquired. But it is common knowledge that with the present system of education the latter happens with nine boys out of ten. In any case, this association exists already at an early age, and no matter how it may be acquired, there is nothing voluntary in it. It is likewise difficult to explain why early sexual sensations are associated with the image of one particular woman and not with the image of another, or of woman in general. But one thing is clear: sexual sensations can hardly be associated with the images of those women who constantly surround the boy. Since the boy has known these women for a long time he associates them with other sensations, which are also of an emotional nature, but which greatly differ from sexual sensations; they are of a very pronounced character due to the frequent repetition of reflexes in which these women act as stimulators on the boy's sense organs. It is obvious that the image of these women evokes strong sensations in his mind, and even if they are associated with sexual sensations, these latter cannot be noticed because they are relatively weak. (For example, we are unaware of the thoughts associated in each of us with reflexes from the stomach, though such associations undoubtedly exist.) That is why boys first fall in love with dim, uncertain images—their ideals. To the boy this image is of the same importance as the image of a knight, though accompanied by different sensations. It is obvious that in the course of the boy's experience various properties, in the shape of images and sounds, may be bestowed to this elastic form. Despite its seemingly poetic character, this process is still nothing but a frequent repetition, influenced by real encounters with women, of a reflex with an ideal feminine image. When this ideal firmly grips the boy's imagination he begins to attribute to it all the properties which he loves not only in women, but even in knights. When, finally, the ideal has assumed a more or less definite shape, and the boy encounters a woman who resembles this ideal, he, so to speak, transfers his dream to her and begins to love her as the embodiment of his dream. In our terminology, he has associated his emotional ideal with a real image. This is the so-called platonic love. The sex element here is only slightly pronounced, because compared to vivid and, consequently, emotional, visual and aural sensations, sexual desires are as yet unsettled and vague. For the same reason, love, notwithstanding its highly subjective character as a sum of emotional sensations, is more objective than any other emotion. This is the source of the noble side of man's love for woman: he learns not to be an egoist, because he loves someone as much as himself, and sometimes even more. A word of explanation is needed here. When a man loves a woman, he, properly speaking, loves in her his own pleasures; but he objectifies the latter and regards the woman as the source of all his pleasure; thus the radiant image of the female possessing all the virtues appears in his consciousness along with the image of himself. He loves the woman more than himself because he will never attribute to his ideal those of his emotional feelings which are unpleasant. Man attributes to the beloved only the best side of his pleasure. After what has been said there is no need to prove that such emotion inevitably leads to so-called self-sacrifice, i.e., may contradict man's natural instincts, even the voice of self-preservation.

Then the time comes when the man begins to possess his ideal. Now his emotion is intensified, because instead of vague, indistinct sexual desire there arise the vivid, palpitating sensations of love, and the female appears in all her splendour. However, months pass, or a year, or two at most, and the emotion burns out even in those fortunate cases when reality fully conforms to the ideals on both sides. What is the reason? The reason is that the vividness of emotion is maintained only by the changeability of the emotional image. After a year or two of joint intimate life, all possible changes become completely exhausted on both sides, and the vividness of emotion disappears. Love, however, does not disappear: owing to the frequent repetition of reflexes, where the image of the beloved with some or all of her qualities constitute the psychical content, her image is associated, so to say, with all the movements of the lover's soul, and she really becomes his other half. This is love by habit—friendship.

He who has once experienced these natural stages of complete love rarely loves passionately a second time. Repeated emotions usually indicate dissatisfaction with the previous emotions.

This concludes my examination of the development of emotions. The foregoing examples show that these phenomena, too, are essentially reflexes, but complicated by the addition of emotional elements and because of this expressed outwardly in movements which are more intense than the usual ones. It is due to this factor, making emotion perceptible, that I have named such reflexes *psychical reflexes with an intensified ending*. Fear, which we discussed in the chapter on involuntary movements, undoubtedly also belongs to the sphere of emotions, both from the point of view of psychical content and of its external manifestation. Hence, the hypothetical scheme of fright, with which the reader is already acquainted, is, at the same time, the anatomical model of the mechanism of emotion.

Now a word about the external manifestations of the highest degrees of emotion—enthusiasm and ecstasy—which seem to differ from the general rule being distinguished by immobility. Actually this state, despite its external manifestations commonly known as numbness, torpor, etc., is not absence of movement. On the contrary, it is connected with movement, otherwise enthusiasm would not be expressed outwardly; what is more, in this state movement is even considerably intensified, the contraction of the muscles being here in the nature of a more or less protracted petrifaction. This explains the immobility, the petrified forms of the outward manifestations of enthusiasm. The process is exactly the same as in the highest degrees of terror. Consequently, in this instance the mechanism of inhibition of movements plays no role whatever.

§ 14. After examining the process of inhibition of reflex movements and after showing that the chief result of these acts is a psychical reflex minus its last component, i.e., thought, I directed the reader's attention to those properties of thought which enable man to separate in his consciousness thought from action, even when the action is performed mentally. It was pointed out that the knowledge of their relationships would be of importance subsequently, when studying the illusions of self-consciousness. Now I shall try to do the same with regard to desire and action:

The reader is already aware of the place occupied by desire in an emotional reflex. It invariably appears when the emotional reflex remains uncompleted, i.e., unsatisfied. From this point of view desire and thought are identical. However, since in most cases desire in an adult is caused by a certain notion, or a series of notions, i.e., thought, the desire is, of course, merely the emotional side of thought. It follows, then, that the conditions for distinguishing desire from the action induced by it, i.e., from the act of satisfying the desire, even when the act takes place only in thought, are the same as those described above. In this case, the above-mentioned conditions are even more distinct, because desire as a sensation is always of a more or less oppressive, negative nature; conversely, the sensation which accompanies action, i.e., the satisfaction of emotional desire, is always of a vivid and positive character. Hence it is clear that mentally I can desire something more or less passionately, i.e., long for satisfaction of my desire. Outwardly this act is expressed in the words: "The man is thoughtful." If you ask him what he is doing he will answer: "I am thinking." "What are you thinking about?" "I intend, I desire, I wish, I long to do this and that." Choice of words will depend on the more or less emotional nature of the thought. Thus, the words "desire" and "wish" are practically identical; yet they are frequently used to denote different things. It is usually said that desire is capricious, and like everything emotional, contradicts will to a greater or lesser degree, whereas wish is often regarded as an act of will. "*I do not wish to fulfil my desire, and I shall not do so. Being tired, I am sitting; I should like to lie down, but I remain sitting.*" The wish to remain sitting, despite the desire to lie down, is regarded as an absolutely unemotional act. *It is believed that man can act against his desire, if he so wishes* *(unemotionally)*. I am tired and am sitting, I should like to stretch out, but I get up and begin to work. Here the unemotional wish to get up is, of course, stronger than in the first case. In general, in the languages of different peoples and in their consciousness unemotional wishing, or will, appears as a limitless power. Even the French, who are one of the most volatile and emotional peoples in Europe, say: "*vouloir c'est pouvoir*", meaning that the power of will, or of unemotional wishing, knows no limits.

The reader will see therefore that there is a certain confusion either in the usage of words which expresses sensations, or in the sensations themselves and in the concepts and words associated with them.

Let us try to clear up this confusion.

First, we must agree on terminology. Given an almost unemotional psychical reflex in consciousness, i.e., in the form of thought, we shall call "*wish*" the element of emotional striving for completion of the reflex, i.e., for satisfaction of the emotion—"*I wish to do this or that.*"

If the reflex is of a strongly pronounced emotional character, we shall call the same side of the reflex "*desire*".

So, having agreed on terminology, we shall now consider cases when an unemotional wish, so to say, overpowers desire.

I am tired and am sitting. The feeling of fatigue inevitably impels me to lie down (I desire). Is it possible to remain sitting if at the given moment there is no reason whatever for doing so? No, it is impossible. Obviously, there must be a reason for the unemotional wish to remain sitting; the presence of this reason is determined by the fact that wish, in our definition, is the element of striving in a thought. Even when a person remains sitting in a completely voluntary way, i.e., *merely out of caprice*, there is always a reason for it; everyone will say that this gentleman is not very tired and that his caprice is stronger than his fatigue.

The same applies when a person wishes to do something against his desire, and actually does it. The result, i.e., the action, is the inevitable consequence of the person's wish which is stronger than his desire.

But the reader may ask: How can a less emotional thought overpower a more emotional one? The point is that in many cases the first is only seemingly unemotional. When I am tired, the feeling of fatigue is, of course, more distinct than all other feelings; however, I do not go to bed, being, for example, afraid that if I fall asleep I may be bitten by a snake. Given different conditions I would tremble at the thought, but now I remain sitting quietly; and it is fatigue alone which I clearly feel in addition to this thought. The matter will be different when, being tired and fearing snakes, I suddenly see one nearby; in this case the sensation of fear will manifestly overbalance the feeling of fatigue, and I shall take to my heels. Here is another case when an absolutely unemotional wish overcomes emotional thought. Being strictly punctual, I do not go to bed—though I am tired—because I am afraid that I shall fall asleep and be late for my appointment; I do so although I realise that there would be no great misfortune in my being late. Here, the power of the thought which keeps me from going to bed is determined by the habit of punctuality, i.e., by the frequent repetition of the reflex in this direction. What has been done a thousand times is easily done for the thousand and first time.

The reader will appreciate that in all cases of this kind there is a certain reason for every *wish*, and if the wish is stronger than the *desire*, the former always takes the upper hand. The reflex does not thereby lose its reflex nature. Definite external influences evoke a consecutive series of associated thoughts, and the end of the reflex is the logical result of the strongest thought. In many cases, however, the cause of a wish cannot be established, and then it seems that the wish arises causelessly. Here is what, in my opinion, is a striking example.

To prove that my argument concerning unemotional wishing is nonsense, my opponent demands from me an explanation of the following fact. He says: "*I think that I wish to bend my finger in a minute; I actually* do so (and he bends his finger within the minute); *I am absolutely conscious of the fact that the beginning of this act originates within myself, and that every moment of it is under my control.*" To prove that the act really originates in himself, my opponent asserts that he can repeat it at any time of the year, in the daytime as well as in the night, on the summit of Mont Blanc or on the Pacific coast, standing, sitting or lying—in short, under any conceivable external conditions, provided, of course, he is conscious. From this he draws the conclusion that wish does not depend on external conditions. His conviction that he has power over every moment of the act is based on the fact that he can bend his finger at will not only in one minute, but also in two, three, four or five minutes, and bend it slowly, quickly, and still quicker.

I shall try, as far as possible, to show the reader that my opponent, despite the arguments which speak in favour of his judgement, bends his finger mechanically.

First, the very conversation between my opponent and myself concerning unemotional wishing cannot begin without a cause, in Lapland or in Petersburg, during the day or at night, standing or lying—in short, in any place or at any time. There is always a reason for the conversation. However, one can put forward the following objection: the conversation is fully under the control of my opponent, since it is his will to speak or not to speak. The answer to this is quite easy: there must be special causes for both cases. If one of them is stronger, it will predominate. My opponent has begun to speak and this means that he could not help speaking.

But once he has begun to speak on the subject under our consideration, he will do so without any further external influence: he may close his eyes, stop his ears, etc. It is immaterial whether he is in Europe or in Asia, on the top of a mountain, or in bed—in short, everywhere he will speak in the same way. What is the reason? It is very simple: throughout his life he has performed millions of voluntary movements with his arms, legs, tongue; in millions of cases he has refrained from making such movements at will; thousands of times he has named these movements, or has thought of them as of acts of will; consequently, the notion of the entire act with its name is associated in my opponent with practically all possible objective external influences, so that this psychical formation cannot be influenced by the view of surrounding nature, by cold, or by posture of the body, i.e., by any external factor. Thus, the thought has come into my opponent's head in the given form inevitably. But the reader may ask: Why did your opponent express his idea precisely by bending the finger and not by some other movement?

To that I can only give a general answer. Man performs most of his movements with his eyes, tongue, arms and legs. However, the expression "man's movements" is much more frequently associated with the movements of the arms and legs than with those of the tongue and eyes; naturally, this is because the tongue is not visible during speech and the movements of the eyes are too rapid and short to be noticed, while the movements of the arms and legs are clearly manifest. In any case, when we speak of voluntary movements, it is incomparably easier to illustrate them by a movement of the arm or leg, than by any other movement. Further, the arms are more suitable for this purpose than the legs, being much more mobile and less occupied. Persons who get excited when speaking, always move their arms and only in extreme cases move their legs. It is natural, therefore, that the arms should be used more readily than the legs to illustrate one's thought. But in the upper limb as a whole it is the hand which is more mobile and used more than all other parts. Indeed, in most movements of the upper limb the fingers move at least ten times when the arm bends at the elbow or turns on its longitudinal axis only once. Hence, it is quite natural to illustrate a thought, similar to that now being considered by us, by the movement of a finger, namely, by bending it, which is the most frequent act. But what does the word "natural" imply? It implies that the movement of the finger follows the above-mentioned thought of its own volition, i.e., involuntarily. Thus, my opponent, without having noticed it, or to be more precise, being sure that he had noticed the opposite, first thought, then spoke and, finally, moved his finger quite inevitably and involuntarily. But why did he think first, and move his finger a minute later? Because thought usually precedes movement. The reason for the definite interval between the thought and the movement lies in the very nature of my opponent's act. He wants to show that he can choose the time of the movement at will (he himself says so). But why did he choose precisely one minute, and not two, three, or five? The answer in this case is the same as to the question why my opponent chose the movement of a finger and not of some other limb to illustrate his thought: a minute is longer than a second and at the same time not too long. My opponent knows that any interval is suitable, but the shorter it is, the better.

We see, therefore, that my opponent is really under the delusion of his self-consciousness: his entire act is nothing but a psychical reflex, a series of associated thoughts evoked by the first impulse to conversation and expressed in a movement which logically follows from the most powerful thought.

Hence, an unemotional wish, no matter how independent of external influences it may seem, actually depends on these influences as much as any sensation. Whenever the cause of the wish cannot be determined, as in the example just considered, the result of this wish is not strong. Conversely, if an unemotional wish triumphs in the struggle with a powerful emotional desire, the former is based either on a thought with a very emotional substratum, or on a thought which has become strong as a result of frequent repetition, i.e., habit. The man of high moral principles, mentioned at the beginning of the chapter on voluntary movements, acts as he does solely because he is guided by the high principles acquired by him in the course of his life. Prompted by these principles he cannot act otherwise: his activity is the inevitable result of these principles.

After what has been said it is hardly necessary to analyse in detail the typically voluntary activity of man, described in the beginning of the chapter on voluntary movements. Readers who appreciate and accept my point of view do not need this analysis; those who do not, will not be persuaded by any further reasoning.

And so, the question of whether the most voluntary of all voluntary actions of man depend on external and internal conditions has been answered in the affirmative. From this it inevitably follows that *given the same internal and external conditions the activity of man will be similar.* Choice of one of the many possible ends of the same psychical reflex is absolutely impossible; its apparent possibility is merely a delusion of self-consciousness. The essence of this complex act is that apparently one and the same reflex with the same psychical content is reproduced in man's consciousness in the form of thought; however, this reflex takes place in more or less different conditions and is, therefore, expressed in different ways. If one of its ends is of a more emotional nature, you will want to act accordingly; if a less emotional but stronger image emerges in your mind and draws you in the opposite direction, the reflex will have another end in your thought. Ultimately conditions arise for the reflex to manifest itself, and we see that in half the cases the plans vanish and we do not act as intended. Even those who firmly believe in the voice of self-consciousness say in these cases that we have lost control of the external conditions. But in our opinion, this clearly shows that the *initial cause of any human activity lies outside man.*

My task is nearing its end. Thought in the broadest sense and the external activity induced by it exhaust the whole range of the highly diverse conscious life of man. I have answered all the questions posed as clearly as possible.

Now it remains for me to point out the very great deficiencies of the present work and thus show the insignificance of what I have done compared with what will be done in the future.

1) The present work analyses only the external side of psychical reflexes, or, so to say, the paths which they follow; there is no mention whatever of the nature of the process itself. Everyone knows, for example, the sensation of the colour red, but nobody in the world can explain the nature of this sensation. Nor do we know what takes place in the sensory or motor nerve when excited. It is all the more impossible, then, to comprehend the nature of more complex psychical acts. The reader may ask: How then can one speak of the paths of reflexes? But this is quite possible: although we do not know what takes place in the nerves, muscles and brain centres during excitation, we cannot but see the laws of pure reflexes and regard them as true. He who accepts this, is obviously entitled to look for similarity between any phenomenon, for example any conscious act of man, and a reflex. Whenever we find this similarity (and I am sure it can be found, but my conviction is not an absolute truth for everybody), we say that the conscious act and the reflex are similar in their nature. This is what I have done in this work.

2) Proceeding in my investigation from the phenomena of pure reflexes, I must thereby accept the hypothetical side of the teaching on reflexes. For example, the idea that the nerve centre connecting the sensory and motor nerves is a nerve cell is a

highly probable hypothesis, but, a hypothesis, and nothing more. Further, assuming the existence in man of centres inhibiting and intensifying reflexes, I thereby admit another hypothesis, because I carry over phenomena which have been observed in the frog directly to man. The existence of such centres in man is highly probable, but it has not yet been definitely proved. "But what, then, is your teaching in essence?", the reader may ask. To this I reply: My teaching is pure hypothesis to the extent that it concerns the existence in man of three separate mechanisms controlling the phenomena of conscious and unconscious psychical life (i.e., the mechanism of pure reflex and the mechanisms which inhibit and intensify reflexes). Those who regard this hypothesis as being doubtful and insufficiently substantiated, or who simply cannot accept it, can, of course, reject it; but that will not affect my propositions in the least, because my chief task was to show that all acts of conscious and unconscious life are reflexes by origin. As to the explanation why the ends of these reflexes are extremely weakened in some cases and intensified in others, that is a matter of secondary importance. I shall be the first to congratulate anyone who finds a better explanation.

3) In the present investigation nothing is said about the individual peculiarities of the nervous mechanisms in the newborn child. These peculiarities undoubtedly exist (ancestral and inherited from the nearest kindred), and they must, of course, influence man's entire subsequent development. However, it is absolutely impossible to detect these peculiarities, because in the overwhelming majority of cases $^{999}/_{1000}$ of the psychical content of man is determined by education in the broadest sense, and only $^{1}/_{1000}$ depends on individuality. By this I do not mean to say that a fool can be made intelligent; this would be the same as trying to develop hearing in a person born without the auditory nerve. What I have in mind is that a clever Negro, Lapp or Bashkir brought up in European society and in a European manner will differ very little intellectually from educated Europeans. But I could not enter into an examination of these highly interesting problems. In my opinion, there was no need to do so. When analysing the acts of conscious life from the point of view of their origin I had in mind a highly developed

psychical type. And if my basic propositions can be applied to the activity of this type, then they are all the more applicable to less developed types.

4) Our interpretation of memory and of the reproduction of psychical formations is also based on a hypothesis—the hypothesis of latent traces of nervous excitation. To naturalists there will be nothing unusual about this hypothesis, especially because the phenomena of memory, as shown by us, are in the main akin to the phenomena of perceptible traces of light which appear after every real optical stimulation. The following fact, in addition to what has been said earlier, will help prove this. It is known that the traces of light are the more distinct the less light acts upon the eyes after stimulation by an external object. For example, after looking at a burning candle we close the eyes and then cover them with the hand in order to make the trace of the candlelight clear. The same applies to reproduction of images in thought. They are particularly distinct in sleep, when very little light acts on the eyes and when the other senses are at rest. As is known, it is best to think in images in darkness and absolute silence. Only a mentally disordered person suffering from visual hallucinations, i.e., from disorders of the nervous system, can think in images in a noisy and brightly lit room.

In any case, the hypothesis of latent nervous excitation explains the most delicate sides of psychical acts without overstepping the limits of physical possibility.

5) Finally, I must confess that I have framed these hypotheses without any great acquaintance with psychological literature. I have only studied Beneke,[27] and in my student days at that. I have obtained from his works a general idea of the teaching of the French sensualists.[28] Experts in psychology, i.e., professional psychologists, will probably point out defects in this investigation. But my task was to show them the possibility of applying physiological knowledge to the phenomena of psychical life, and I hope that I have succeeded, even though partly, in attaining my aim. It is this circumstance that justifies my decision to write about psychical phenomena without having any preliminary knowledge of what has already been written on this subject, knowing only the physiological laws of nervous activity.

After reading this long list of hypotheses from which my views on the origin of psychical acts derive, the reader will probably ask once more: Why should I relinquish my belief in the voice of self-consciousness which tells me many times a day with absolute clearness that the impulses inducing my voluntary acts originate in myself and are not, therefore, the result of external stimulations, except, perhaps, those which support the life of the body?

If what I have said is not sufficient to prevent questions of this kind, I ask the reader to consider the following well-known phenomena. When a person, being physically very tired, falls into a *deep sleep*, his psychical activity sinks to zero, and in this state he does not dream; he becomes highly insensitive to external stimuli: neither light, noise nor pain can awaken him. This simultaneous loss of sensitivity to external stimuli and complete absence of psychical activity are also encountered in cases of alcoholic intoxication, chlorophorm narcosis and fainting. Everybody knows this, and no one doubts that the two acts are causally interrelated. The only difference in the views on this matter is that some people regard loss of consciousness as the cause of loss of sensitivity, while others assert the opposite. Actually, however, there can be but one point of view. If one, two, three or a hundred guns are fired near a man in deep sleep, he will awaken and his psychical activity will reappear at once; but should the man be deaf, theoretically even a volley of a million guns would not bring him back to consciousness. The same is true of optical stimuli of any strength in the case of a blind person; this is likewise true of the most terrible pain in the case of a person deprived of cutaneous sensitivity. In short, a man in deep sleep and having no sensory nerves would not awaken till his death.

Now let anyone try to contend that psychical activity and its expression—muscular movement—are possible, even for a single moment, without external sensory stimulation!

NOTES

REFLEXES OF THE BRAIN

1. The history of the "Reflexes of the Brain" and the difficulties associated with the publication of this work, were described in detail by Sechenov in his *Autobiographical Notes*:

"I returned to Petersburg in May 1863 and spent the summer writing a treatise which played a definite role in my life. I have in mind the 'Reflexes of the Brain'. The dissertation which I wrote for my doctorate in 1860 contained the following two theses:

"'All the movements known in physiology as voluntary movements are reflex movements in the strict sense of the word', and 'the most general feature of the normal activity of the brain (expressed in the form of movement) is the disproportion between the excitation and the effect (movement) engendered by it'.

"The first of these theses is quite clear, the other requires a certain explanation. In the absence of any influence of the brain, the sensory stimulations and the reflex movements caused by them correspond to each other in intensity, i.e., weak stimulations evoke weak movements, and vice versa; but given the influence of the brain, no such conformity is observed: a weak stimulation may evoke a very strong movement (for example, the whole body starts at a sudden light touch) and, conversely, a very strong stimulation may not evoke any movement at all (as in the case of a person suffering acute pain and remaining outwardly immovable). If to this we add that at the time I was preparing my dissertation I could not but be aware of the three elements which comprise the reflex acts, and of the psychological significance of the intermediate members of the acts which end in voluntary movements, it will be clear that the idea of establishing the physiological substratum of the psychical phenomena with regard to the mechanism of their formation had come into my mind already at the time of my first visit abroad; this is all the more so, because in my student days I used to study psychology. There is no doubt that ideas of this kind were maturing in my mind also during my stay in Paris, because there I was engaged in experiments directly connected with acts of consciousness and will. In any case, upon my return to Petersburg from Paris these ideas took the shape of the following, partly unquestionable and partly hypothetical propositions: in his everyday conscious and semi-conscious life man is never free from the sensory influences exerted by the environment through his sense organs, as well as from sensations ensuing from his own organism (his own feelings); it is these factors which maintain his entire psychical life with all of its motor manifestations, because psychical life is inconceivable when the senses are lost (this supposition was confirmed twenty years later by observations on very rare cases of patients who had lost almost all their senses). Just as man's movements are determined by the indications of the sense organs, his mode of behaviour in psychical life is determined by desires and wishes. Both the reflexes and psychical processes resulting in action, are of an expedient character. The beginning of the reflex is always caused by a certain external sensory influence; the same thing takes place—often imperceptibly—in the whole of our psychical life (since in the absence of sensory influences psychical life is impossible). In most cases the reflexes end in movements; but there are reflexes which end in the suppression of movement; the same thing can be observed in psychical acts; most of them are manifested in facial expressions and actions, but in very many cases their ending is suppressed, with the result that instead of three members the act consists only of two; the meditative mental side of life takes on this form. Emotions are rooted, directly or indirectly, in the so-called systemic senses which can develop into strong desires (sensation of hunger, instinct of self-preservation, sexual desire, etc.) and which are expressed in impetuous actions; for this reason they can be included in the category of reflexes with an intensified ending.

"These considerations formed the foundation of a small treatise to which I gave the title 'An Attempt to Establish the Physiological Basis of Psychical Processes'. The editor of the medical journal to whom I submitted the manuscript informed me that the censor's department insisted on a change of title (I rather think that the editor himself thought the title was not quite suitable for a purely medical journal). So I changed the title to 'Reflexes of the Brain'. This earned for me the charge that I was an involuntary propagator of immorality and nihilistic philosophy. Unfortunately, the censors' regulations of that time prevented me from publishing an explanation which would have easily dispelled the misunderstandings. Indeed, my sternest opponents can accuse me of asserting that every action, irrespective of its content, is predetermined by the nature of the given individual; that any action is caused by a certain, sometimes insignificant, external stimulus; that the action itself is inevitable and, that being so, even the worst criminal is not responsible for his crimes. They can say, moreover, that my teaching gives the green light to shameful deeds by persuading depraved persons that they are not responsible for what they do, seeing that they cannot help doing so.

"This last charge is due to an obvious misunderstanding.... There was no need to discuss in my treatise the matter of good and evil; my object was to analyse actions in general, and my point was that, given certain conditions, not only actions but also their inhibition are inevitable and obey the law of cause and effect. Is this an apology for immorality?" (*Autobiographical Notes by Ivan Mikhailovich Sechenov*, U.S.S.R. Academy of Sciences, Moscow-Leningrad, 1945, pp. 113–16.)

Sechenov sent his manuscript to the magazine *Sovremennik*, the views of which were similar to his own. However, the censor's department banned it, and for this reason the treatise had to be published serially in the weekly *Meditsinsky Vestnik* (Nos. 47 and 48, 1863). Three years later, in 1866, this classical work—partly revised—was published in book form after traversing a long and thorny path of censorial persecution.

A study of the archives has made it possible fully to reproduce all the stages of Sechenov's struggle to overcome the difficulties associated with the publication of his "Reflexes of the Brain".

Of particular interest is the indictment formulated by the St. Petersburg Censors' Committee when bringing an action against Sechenov. In a document addressed to the attorney of the District Court on June 9, 1866, the Censors' Committee motivated its charge and described the "Reflexes of the Brain" as follows: "This materialistic theory reduces even the best of men to the level of a machine devoid of self-consciousness and free will, and acting automatically; it sweeps away good and evil, moral duty, the merit of good works and responsibility for bad works; it undermines the moral foundations of society and by so doing destroys the religious doctrine of life hereafter; it is opposed both to Christianity and to the Penal Code, and, consequently, leads to the corruption of morals."

The publication of the "Reflexes of the Brain" made a tremendous impression on the progressive circles of Russian society. It became the handbook of the young people of the eighteen-sixties. People were deeply stirred by it, and it was the subject of lively discussion; and while it won many friends, it also made many enemies in the camp of the reactionary idealists. The book played a decisive role in the education of that generation of Russian physiologists who are regarded as the glory and pride of Russian science.

Pavlov had high praise for this book (see, for example, Pavlov's *Complete Works*, Vol. III, Book I, published by the U.S.S.R. Academy of Sciences, 1951, p. 249, and also Pavlov's address at a Sechenov memorial meeting on March 22, 1907, published in the *Proceedings of the Russian Medical Society*, St. Petersburg, March-May 1907).

I. Mechnikov, K. Timiryazev, A. Samoilov, N. Wedensky and other scientists referred in their reminiscences to the scientific and social value of this book.

The "Reflexes of the Brain" was violently attacked by the idealists the moment it appeared and throughout the subsequent years (N. Strakhov, E. Edelson, whose pen-name was "E. E-n", K. Kavelin, M. Ostroumov, Z. Radlov, G. Chelpanov, A. Stadlin, and others). However, among Sechenov's critics were some who belonged to the democratic movement of the sixties. The magazine *Russkoye Slovo* edited by D. Pisarev reacted to the "Reflexes of the Brain", not with a review, but with an article headed

"The Last Philosopher-Idealist", written by V. Zaitsev and devoted to Schopenhauer. The author of this article, while acknowledging the importance and theoretical value of Sechenov's views on the complex philosophical questions concerning the origin of the concepts of time and space, misunderstood Sechenov's teaching as a whole and wrongly interpreted it. M. Antonovich, a friend of Chernyshevsky, published in the *Sovremennik* a reply to Zaitsev in which he supported Sechenov's views. p. 1

2. In the first edition of the "Reflexes of the Brain" the word "psychical" was absent. Introducing this word in the second edition, Sechenov deemed it necessary to emphasise that his purpose was to make a physiological analysis of the psychical activity of the brain, not its activity in general. p. 2

3. Eduard Friedrich Weber (1806-1870)—author of the *Mechanism of the Human Body* written jointly with his brother, Wilhelm Eduard Weber, physiologist (1804-1891). A third brother, Ernst Heinrich Weber (1795-1878), was a well-known physiologist and anatomist, professor of the Leipzig University and the author of a number of works on psychophysics (the famous Weber-Fechner law was named after him.) p. 13

4. Eduard Pflüger (1829-1910)—German physiologist; was professor of physiology of the Bonn University. p. 13

5. Claude Bernard (1813-1878)—outstanding French physiologist—was member of the Academy of Sciences and Head of the Chair of Physiology, Sorbonne. Bernard greatly influenced the development of physiology in the second half of the nineteenth century. At one time Sechenov worked in his laboratory. p. 13

6. I. Rosenthal (1836-1915)—professor of the Berlin Physiological Institute, author of the book *General Muscular and Nervous Physiology* translated into Russian by I. R. Tarkhanov. The first edition of the "Reflexes of the Brain" did not contain any reference to the work of Rosenthal; neither was there any graphical scheme of the "reflex machine" nor any mention of the experimental data obtained by Berezin (see note 7). This is explained by the fact that in the interval between the publication of the first and the second editions, i.e., between 1863 and 1866, Sechenov and his pupils had accumulated new data concerning the mechanisms which inhibit reflex movements, and introduced greater clarity into the anatomical concept of the peripheral and central apparatuses participating in the formation of reflex arcs at different levels of coupling. This explains why in the second edition the end of §4, beginning with the reference to Rosenthal's work, differs from the first edition, though the basic ideas are unchanged. p. 14

7. I. G. Berezin (1837-1866)—Russian physiologist and pupil of Sechenov. In 1863 Berezin graduated from the Medico-Surgical Academy, remained in the Academy and did physiological research in Sechenov's laboratory. p. 15

8. Here the term "conscious sensation" is used by Sechenov for the first time. Later, developing his views on the nature of sensations, he differentiated them according to the degree of their perceptibility. Sechen-

ov identified the concepts "perceptible sensations" and "conscious sensations". p. 19

9. See Note 7. p. 20

10. V. V. Pashutin (1845-1901)—a patho-physiologist and pupil of Sechenov and Botkin, who raised pathophysiology to the level of an independent experimental discipline and created the first Russian school of pathophysiology. p. 21

11. The question of the influence of "the physiological state of the nervous centre" on the nature of sensation, posed here by Sechenov, acquired in physiology the significance of an independent subject which gave rise to a special trend in physiological investigation. Sechenov's pupil N. Wedensky should be regarded as his direct continuer in this branch of research. p. 23

12. Sechenov was the first to use the term "vague" in characterising the muscular sense; sometimes he also used the term "obscure". These concepts became firmly established and widespread; they gave an impetus to many investigations which were specially aimed at ascertaining the role of the muscular sense in human behaviour. By means of these figures of speech Sechenov emphasised the important idea that the signals emanating from the muscular sensations leave a vague impression in the consciousness, and sometimes even do not reach it at all. Sechenov reverted to the question of muscular sense in many of his works. When substantiating his theory of locomotion, he devoted much attention to the analysis of muscular sense as a regulator of movements. The physiologist A. Samoilov, one of Sechenov's pupils, characterised the importance acquired by this aspect of Sechenov's teaching (A. F. Samoilov, *Selected Articles and Speeches* published by the U.S.S.R. Academy of Sciences, 1946). The significance of Sechenov's works in this field was elucidated also by K. Kekcheyev who devoted a special investigation to proprioceptive sensations and showed that the modern teaching on proprioception is based on Sechenov's principles concerning the muscular sense (K. Kekcheyev, *Interoception and Proprioception and Their Clinical Significance*, State Medical Publishing House, 1946). p. 37

13. The striking cases described here by Sechenov can be fully explained by the operation of the conditioned-reflex mechanism. Over the years firm connections are established between definite parts of the day and the sensations invariably accompanying these parts (partly reaching the consciousness and partly not), on the one hand, and definite actions—on the other. Thus, definite parts of the day become, as it were, conditioned stimuli. In the case of the cook, the movements were performed automatically, but at one time they had been acquired by learning. The same conditioned reflex mechanism explains the second case described by Sechenov. p. 39

14. Sechenov's idea that "persons who are deaf from birth never learn to combine sounds into words" cannot be regarded as conforming to reality. Actually the training of deaf-and-dumb persons is based on the fact that in this case "the muscles participating in speech" (which Sechenov mentions in his work) establish a connection not with the aural but with

visual sensations (watching the movements of the teacher's lips), tactile and muscular (feeling the cervical muscles of the teacher while he pronounces separate sounds), olfactory, gustatory and others, for example, the sensation of vibration which adequately compensates for defects of hearing. This fact was, apparently, unknown to Sechenov, because the training of deaf-and-dumb people made considerable headway (especially in the U.S.S.R.) long after the appearance of his "Reflexes of the Brain" This, however, does not refute Sechenov's basic idea of the importance of hearing for the development of speech, especially since in his subsequent article "Who Is to Elaborate the Problems of Psychology, and How?" he somewhat changed his original viewpoint by acknowledging the possibility of training deaf-and-dumb persons to speak. p. 51

15. When using the expression "decomposition of concrete impressions" Sechenov implied under the term "concrete impression" a non-differentiated reflection of an object caused by the activity of the sense organs. Decomposition is, in Sechenov's opinion, an analysing activity Here Sechenov's view on the sense organs as analysers begins to take shape. The connection between his views and those of Pavlov on the essence of analysers is quite obvious. Sechenov's research paved the way for Pavlov's thorough and profound substantiation of a teaching on the sense organs as analysers (I. P. Pavlov, *Complete Works*, Vol. III, Book 1, 1951). p. 55

16. Sechenov explains the difference between the visual, aural and tactile perception of the various properties of external objects not only by the different "analytical power" of the corresponding "sensory apparatuses", but also by the uneven development of the visual, aural and tactile faculties, depending on man's requirements and social activity. This point of view, and especially the fact that Sechenov emphasised the role of man's requirements and exercise in developing his analytical faculties, is fully in accord with the present-day materialistic approach to the laws of development of the sense organs. In his interpretation of the problem of requirements and exercise Sechenov rehabilitated the remarkable (both for his time and for ours) ideas of Lamarck which had been misunderstood by many people and undeservedly forgotten. In Sechenov's interpretation these ideas appeared in an entirely new light due to the fact that he could free himself from the naïve mechanistic conception of the nervous fluid—the cornerstone of Lamarck's psycho-physiological views—and rise to the level of strictly materialistic physiology. p. 57

17. Sechenov's idea that "the number of psychical acts is increased many thousand times" as a result of countless associations of notions "from all sensory spheres" is close to the teaching of Pavlov who proved that any external agent can be a conditioned stimulus, and that the number of temporary links, especially in man, can, therefore, be unlimited (I. P. Pavlov, *Complete Works*, Vol. IV, pp. 52-53). p. 61

18. Jan Purkinje (1787-1869)—outstanding Czech anatomist and physiologist. His scientific activity was extremely broad. His fundamental physiological works were devoted to the study of the sense organs. The change which takes place in the brightness of coloured objects in con

ditions of reduced illumination is known as "the Purkinje phenomenon". p. 69

19. Sechenov opposes fractional sensations to concrete sensations. By concrete sensations he implied those which produce an integral image combining all the diverse attributes of the object. In these cases, psychology generally uses the expression "perception of an integral object". Sechenov, who actually attaches a broad sense to the concept of sensation, does not use the term "perception". p. 71

20. According to Sechenov's interpretation, the traces which persist in the brain as a result of the action of the stimulus on the sensory apparatus are material phenomena the nature of which is wholly subject to physiological study, though it cannot always be determined. The theory of traces or so-called engrams was used also by the idealist psychologists who divorced the trace processes from the changes in the material substratum accompanying each sensation. Sechenov imparted to the theory of traces a definitely materialistic character. p. 72

21. The question of various physiological viewpoints concerning the process of "perception of colours" was thoroughly elucidated by S. V. Kravkov (1894-1951), an expert in the psycho-physiology of vision. Kravkov expounded the history of the controversy between Helmholtz, who held that there were three kinds of nervous apparatuses in the organ of vision and advanced the trichromatic theory of colour vision, and Hering who sought for the physiological substratum of the six basic colour sensations (the red, yellow, green, blue, white and black colours) in special chemical reactions of dissimilation and assimilation of substances. The original investigations carried out by Soviet scientists, and above all by S. V. Kravkov, have greatly clarified the theory of colour vision and enriched it with new experimental facts (S. V. Kravkov, *The Eye and Its Functioning*, 4th ed., 1950, pp. 299-334). p. 72

22. Sechenov regards as subjective those sensations which are caused by the action on the sense organs of stimuli located in our organism, or by changes taking place within it (at present these sensations are known as interoceptive and proprioceptive). Sechenov, therefore, includes the muscular sensation in the category of subjective sensations. For Sechenov the visual and aural sensations are objective because the stimuli which engender them are objects situated outside the organism (in modern terminology these sensations are called exteroceptive). p. 73

23. In the first edition of "Reflexes of the Brain" between the words "muscular" and "memory" Sechenov inserted (in brackets) the words "modified tactile". The absence of these words in the second edition shows that Sechenov was not inclined to interpret muscular memory only as modified tactile memory. By designating aural and muscular memory as memory of time, the visual and tactile memory as memory of space, Sechenov merely emphasised the specific features of the muscular and aural sensations, on the one hand, and of the visual and tactile ones, on the other. Actually Sechenov tended against drawing a strict demarcation line between these two kinds of sensations; in his works he repeatedly pointed out that in man's concrete activity they are often associated

and, acting reciprocally, ensure a more perfect knowledge of the objective world. p. 74

24. This example illustrates in the best possible way the formation of a temporary connection or a conditioned reflex. Here, as on other occasions, Sechenov described in full and correctly characterised the formative process of a temporary connection. Not being able at the time to investigate and reveal this connection by way of experimentation, he had to limit himself to a description. It was left to Pavlov to raise the solution of this problem to the level of an extremely important scientific discovery which marked a turning-point in materialistic physiology. p. 81

25. Sechenov skilfully discloses the reasons for the widespread and erroneous view that thought is the cause of action. He ascribes this error to the illusion of self-consciousness and to the fact that the sensory stimulation, which determines the beginning of each action, often remains unnoticed by the mind, or, as he stated later, "the visible links between thinking and its sensory prototype is completely lost" ("The Elements of Thought"). This proposition, directed against idealist indeterminists, should be regarded as a powerful and effective argument in support of materialism. p. 88

26. In his analysis of the process of development of "lofty moral motives" and "deep convictions", Sechenov confined himself to disclosing the physiological mechanisms of the origin and development of definite associations. It is in this sense that we should interpret his words "their activity [Sechenov has here in mind the "noble types" of people] is the inevitable result of their development". p. 96

27. Friedrich Eduard Beneke (1798-1854)—German philosopher and psychologist who eclectically combined Kantianism with sensualism and empiricism. Beneke regarded psychology as "internal natural science". He is the author of numerous works on psychology, logic and ethics. Beneke's principal work, mentioned by Sechenov, is *Lehrbuch der Psychologie als Naturwissenschaft* (1833). p. 108

28. Referring to the French sensualists, Sechenov had in mind Helvetius, Holbach, Diderot, and especially Condillac—one of the most consistent sensualists, author of the famous *Treatise on Sensations*. p. 108

I. M. SECHENOV

(1829-1905)

All major landmarks in the history of world and Russian physiology are closely linked with the name of Ivan Mikhailovich Sechenov. Pavlov, who carried forward Sechenov's scientific work, called him the "father of Russian physiology".

Appraising Sechenov's role in the development of the natural sciences in Russia in the nineteenth century, his friend Kliment Arkadievich Timiryazev, an outstanding biologist and science historian, wrote: "History will recognise that no other Russian scientist has had such a far-reaching and beneficial influence on Russian science and on the development of scientific thought in our society as Sechenov."

Timiryazev's words have been fully justified: Sechenov's name has become immortal in the history of Russian science.

* * *

Sechenov was born on August 1 (13), 1829 in the village of Tyoply Stan (now Sechenovo), Simbirsk Province (now Arzamas Region). He attended the Military Engineering School in Petersburg where he acquired a sound knowledge of physics and mathematics. Concerning this period of his life Sechenov wrote in his *Autobiographical Notes:*

"... I had a distaste for engineering with its accessories, all kinds of drawing; physics was my favourite subject in the senior grade. My progress in it can be seen from the fact that I was chosen by my physics teacher to be questioned at the final public examination in the presence of Gerua, Chief of the Military Engineers, and other generals. My teacher had just obtained from Germany an electromagnetic machine made by Stehrer and taught me at his home how to operate it. I demonstrated the working of this machine at the examination.... In the junior officer class I conceived a liking for chemistry which was lectured by Ilyenkov (we studied only inorganic chemistry). I remember my examination in this subject as well. I was good at mathematics, and had I entered the Faculty of Physics and Mathematics at the University immediately after leaving the Military Engineering School, I think that I might have become a rather good physicist; however, as we shall see, my destiny proved to be quite different."

The upsurge of social life in Russia towards the middle of the nineteenth century and the tremendous tasks confronting the advanced Russian youth of that time prevented Sechenov from contenting himself with the career of a sapper officer which awaited him after finishing the military school. He decided to enter the Medical Faculty of the Moscow University which greatly attracted progressive young people, since, on the one hand, the profession of physician provided the best opportunities for serving the country, and, on the other hand, the Medical Faculty provided an all-round natural-scientific education and good knowledge of nature, including the nature of man in all its manifestations.

The knowledge of mathematics, physics and chemistry acquired at the Military Engineering School was of great help to Sechenov in his future scientific work. When investigating the organism's intricate vital activity, he always made use of physical and chemical laws.

Among his teachers at the Medical Faculty were outstanding natural scientists and clinicians. One of them was Professor Rulye, biologist and materialist who already in the pre-Darwin period had advocated the idea of the evolutionary development of organisms conditioned by their environment. Sechenov studied the fundamentals of experimental and theoretical physiology under Glebov and Orlovsky, outstanding physiologists of the Moscow University; his first published work was the result of his studies in the clinic headed by the well-known therapeutist Inozemtsev.

Not only the Medical Faculty with its best professors, but the University of the fifties as a whole with its turbulent activity, the lectures by Granovsky so eagerly attended by Sechenov, and the ideological atmosphere created by the brilliant theoretical works of Herzen—this was the school which shaped the outlook of the young physician and physiologist. Upon graduating from the University Sechenov was sent abroad where he spent three-and-a-half years acquainting himself with the great naturalists of the nineteenth century. He worked in the laboratories headed by Du Bois-Reymond, Ludwig and Helmholtz, attended J. Müller's lectures on comparative anatomy and physiology, studied physiological chemistry in Hoppe-Seyler's laboratory and problems of physics in the laboratories of Bunsen and Magnus. During his second sojourn abroad he worked in the laboratory of the renowned French physiologist Claude Bernard.

Already during his first stay abroad the young Sechenov won the respect of his teachers—venerable physiologists—for his initiative and for his ability independently to pose scientific problems and to solve them by way of experimentation.

The period of his preparation for independent scientific activity coincided with a number of highly important events in the development of natural science. The achievements of synthetic organic chemistry, and, above all, the discoveries made by the Russian chemists Zinin and Butlerov, revolutionised physiological thought—they upset the theories about all kinds of "special forces" in organic nature and made it possible to ascertain and master the synthesis of the very substratum of life—organic substances. Ideas testifying to the unity of all chemical processes on earth began to spread all over Europe. Two basic natural laws—the laws of conservation of matter and energy—became the credo of all progressive scientists in the fifties of the last century. Sechenov's stay abroad also coincided with two notable dates in biology—the year 1858, when Charles Darwin read his first paper at a meeting of the Linnaeus Society, and the year 1859 when Darwin's immortal *Origin of Species* first appeared. These highly important events in the history of science greatly influenced the entire development of physiology.

Sechenov's independent research developed under the influence of the philosophical and social ideas advocated in Russia by Herzen, Chernyshevsky and their adherents. In the struggle waged by these men for progressive philosophical and social ideas the development of natural science occupied a prominent place.

Sechenov was one of the first of the physiologists who sided with this great movement in Russian social thought; throughout his scientific life he waged an uncompromising struggle against those who tried to restrict the possibilities of objective physiological study of the complex manifestations in the vital activity of animals and man, including the so-called mental or psychical activity.

Most of the outstanding European physiologists, Sechenov's contemporaries, whose experimental researches paved the way for disclosing the nature of blood circulation, digestion, metabolism, respiration and other processes, were quite helpless when it came to the so-called psychical activity; in their view this activity could not be studied by physiological methods. Sechenov, however, asserted that this form of vital activity was, likewise, subordinated to physiological laws and should be subject to objective experimental analysis.

This conviction logically resulted from his consistent materialistic outlook. Already in his doctor's thesis *Data for the Future Physiology of Alcoholic Intoxication*, which was published in 1860, Sechenov, along with conclusions drawn from his experimental research, set forth a number of philosophical propositions; in particular, he advanced the idea of the material unity of the world, unity of the forces operating in organic and inorganic nature, unity of the organism and of the conditions of its existence; finally, he expressed the idea of the possibility of unravelling the great mystery of consciousness by means of the objective methods of natural science.

Waging a bitter struggle against philosophers and naturalists of the idealist camp, Sechenov already in 1861 formulated the postulate which in those days was of revolutionary significance and which still retains its validity: "The organism cannot exist without its supporting external environment; hence, a scientific definition of the organism should include also the environment which influences it."*

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* *Meditsinsky Vestnik* (*Medical Herald*), No. 26, 1861, p. 242. Two concluding lectures on "The Role of the Vegetative Acts in Animal Life." Lecture one.

In the course of more than forty years of scientific work Sechenov developed and substantiated this important theoretical postulate in numerous researches devoted to the fundamental problem of the correlation between physiology and psychology and to the origin and development of the functions of the nervous system. This postulate governed his experimental investigations in physiology. In all his experiments he proceeded from the idea of the decisive importance of perception of external stimulations by definite sensory elements for the reflex activity of the central nervous system. Sechenov's work in the sphere of the physiology of the higher nervous activity which derives from his fundamental definition of the significance of the unity and interaction of organisms and their environment, was crowned by the major discoveries and generalisations made by his pupil and follower, I. P. Pavlov.

Sechenov's first theoretical research, where he urged the necessity of applying the method of strictly scientific, objective analysis to complex processes designated as psychical,* was his treatise "Reflexes of the Brain", which is rightfully considered the pride of Russian physiology.

This work was sent to the magazine *Sovremennik,* organ of the revolutionary democrats and edited at the time by the famous poet Nekrasov. The original title of the article "An Attempt Physiologically to Explain the Origin of Psychical * Phenomena", failed, as was to be expected, to pass the censor, so Sechenov changed it to "An Attempt to Establish the Physiological Basis of Psychical Processes". The two titles clearly revealed the profound concepts of the scientist which conflicted with the prevailing outlook. The censor regarded the title, to say nothing of the content of the article, as a manifestation of extreme materialism and decided that it could not be published in the *Sovremennik*; they permitted its publication only in a special magazine and under a different title. The treatise appeared in 1863 in the weekly *Meditsinsky Vestnik* under the title "Reflexes of the Brain".

Sechenov remained true to himself: he could not accept a dictated title; nor the cutting by the censor of the last two paragraphs. In the copy which he presented to his wife he erased

* As the title of the Sechenov volume originally published by the Foreign Languages Publishing House and Professor Asratyan's letter indicate (see Professor Rosenblith's Postscript), the word *psychological* has been substituted in contemporary usage for the word *psychical.*

in thick black ink the title "Reflexes of the Brain" and replaced it by the original "An Attempt to Establish the Physiological Basis of Psychical Processes" and inserted the paragraphs killed by the censor.

In "Reflexes of the Brain" Sechenov developed the thesis that from the point of view of their origin, all acts of conscious and unconscious life are reflexes.

He advanced the idea—quite novel for those days—that the entire psychical life with all its motor manifestations is stimulated and maintained by environmental influences which are perceived by the nervous system. He brilliantly substantiated his conclusion that psychical life is inconceivable without stimulation of the sense organs. The propositions that the initial cause of any human action lies *outside man*, and that without external sensory stimuli psychical activity is impossible even for a single moment, were set forth by Sechenov most convincingly.

Proceeding from his fundamental postulate concerning the influence exerted by the environment on psychical activity Sechenov drew far-reaching conclusions which sharply contradicted the contemporary social and pedagogical views. Nor did he stop at the conclusion, which for those days was revolutionary, that all men are equal, that the most backward nationalities can be raised to a high cultural level by means of education and instruction.

Painstakingly elaborating the problems raised in his "Reflexes of the Brain" Sechenov, naturally, arrived at a number of conclusions directly related to the sphere of psychology and introduced into that sphere the method of the physiological analysis on an ever wider scale.

His views, which took final shape within a period of ten years after the publication of his "Reflexes", were expressed in the course of the controversy known in the annals of Russian culture as the dispute between Sechenov and Kavelin. Kavelin's book *The Tasks of Psychology*, which appeared in 1871, was actually directed against the psychological principles expounded in *Reflexes of the Brain.*

In an article devoted to this book Sechenov, with all his customary straightforwardness and bluntness, subjected Kavelin's idealist views to trenchant criticism. Later, he wrote the article "Who Is to Elaborate the Problems of Psychology, and How?" which caused a sensation.

In this article Sechenov sharply criticised the assertions of most of the idealist psychologists that man as a corporeal being is subordinated to the laws of the material world, while as a spiritual being he is independent of them. He again stressed the importance of objective, natural-scientific, physiological study of the complex psychical phenomena, and the possibility of an analytical study of "all the main aspects of the various forms of psychical activity".

The same article contained a masterly outline of a plan for radically revising contemporary psychology with the aim of freeing it from the conglomeration of insufficiently substantiated theories and metaphysical concepts, and of bringing it into the highway of "positive science". Sechenov wrote: "*Only physiology can achieve this, because it alone holds the key to the truly scientific analysis of psychical phenomena.*"

In his controversy with Kavelin, Sechenov maintained that the conclusions revealed in the *Reflexes of the Brain* were correct, and advanced a number of new propositions of great significance for the scientific analysis of psychical phenomena. According to Sechenov, "*by its very subject-matter scientific psychology cannot be anything but a series of theories concerning the origin of the various forms of psychical activity*".

The idea that the principal forms of psychical activity can be regarded as reflex processes had already been expressed in *Reflexes of the Brain*; in his new work he set himself the task of examining the *history* of psychical processes both in the individual evolution of man and in the evolution of the animal world as a whole. He attached particular importance to the study of the laws governing the formation of psychical activity in the course of man's individual development. He stated: "I shall examine the history of the psychical development of man (individual, of course) from birth and try to establish the main phases of this development at different periods, showing that each consecutive phase derives from the preceding one."

Outlining the prospects of further research into the qualitative distinctions between the psychical processes in man and animals Sechenov, proceeding from the history of physiology, showed that acknowledgement of qualitative distinctions, recognition of complex phenomena not yet decomposed into their component elements, in no way signifies acknowledgement of the existence of any special forces. Being a consistent materialist Sechenov left it to the metaphysicians and vitalists to seek explanation in special vital forces; for him any phenomenon developing in the human organism, no matter how complex, could not be divorced from the material processes and should be decomposed into its elements. For the purpose of this decomposition he considered it important to apply the method of comparative study of psychical manifestations in animals. Since the material accumulated by this branch of knowledge at that time was limited, Sechenov merely sketched a programme of research in this direction; he stated that real work on this problem had just begun, adding that this comparative study would be of special importance for the classification of psychical phenomena, as, in his opinion, it would in all probability reduce many complex forms of these phenomena to less numerous and simpler types and, besides, would establish the transitional stages from one form to another.

Sechenov, however, did not overestimate the importance of the comparative method for the investigation of the nature of psychical phenomena in man. As a naturalist and thinker, he constantly had in mind all the aspects of a complex phenomenon and directed attention to the cardinal problem of the essence of human psychical phenomena, namely, the subjective aspect, the so-called conscious element. His statements concerning the qualitative distinctions between the psychical manifestations in animals and man help to formulate the tasks of scientific research.

"But with what are we to compare human psychical phenomena?" he wrote. "To compare them with higher, more complex phenomena is impossible; just below them lies the psychical life of animals which cannot be analysed, and still lower begins the sphere of matter. Should we compare psychical life with the life of rocks, plants and even of the human body?" In posing this profound question, Sechenov advanced the following important proposition: "*Physiology provides a number of facts which establish the affinity of psychical phenomena to the so-called nervous processes in the body, i.e., to purely somatic acts.*"

The key to comprehension of the essence and significance of this proposition is contained in his formulation of the concept of a nervous process. He regarded a nervous *process* as "a partial molecular process taking place in the nerves and nervous centres and inaccessible to our senses", whereas by the term nervous *phenomena* he designated the external manifestations of the nervous activity.

"Unfortunately," he pointed out, "our knowledge of the nervous processes, even in the case of the most elementary reflexes, is negligible. All we know is the material form in which the particular phenomenon develops, some of the conditions of its normal variability, we can artificially reproduce a phenomenon possessing certain characteristics, and we know the role played by some of the parts in the phenomenon as a whole, etc. But the nature of the processes taking place in the nerve and nervous centres is still a mystery. Elaboration or at least elucidation of this aspect of the nervous and psychical phenomena belong to the distant future; we are compelled at the moment to confine our research to external manifestations. Nevertheless, *the concept of a psychical act as a process or motion having a definite beginning, course and end, must be retained as fundamental. . . .*"

Sechenov emphasised the significance of Darwin's teaching for the materialist interpretation of psychical phenomena, pointing out that it leads logically to the necessity of acknowledging the evolution of psychical activity in principle. Proceeding from his evolutionary concept that development of the functions of the nervous system is interconnected with the development of psychical activity, he stated that all aspects of organic life, including the psychical activity of animals and man, derive from the transformation and development of *corresponding substrata*. Since the feature of Sechenov's viewpoint was his daring attempt to link the processes of consciousness with the basic processes (with their development and course) in the nerves and nervous centres, his evolutionary concept raised the question of an historical connection and succession of the basic nervous processes and the processes of consciousness.

Sechenov's writings substantiated the conclusion reached by Engels that Darwin's teaching makes it possible to establish the pre-history of human spiritual activity at different stages of its development—from the elementary forms of irritability of the structureless, but sensing protoplasm of lower organisms up to the thinking brain of man.

Sechenov decided to issue his articles "Who Is to Elaborate the Problems of Psychology, and How?", "Observations on Mr. Kavelin's book *The Tasks of Psychology*", and his treatise "Reflexes of the Brain" in book form under the title *Psychological Studies*. The book appeared in 1873. A French edition came out in Paris in 1884.

The book added to the ferment created by the controversy between Kavelin and Sechenov. Since the very title of Sechenov's book (to say nothing of the contents!) was "an encroachment" on the holy of holies of his opponents—psychology—the attacks on him were numerous. The idealist metaphysicians could not understand how a physiologist, who admitted that his knowledge of various psychological theories was limited, could dare to try and refute these theories and evolve a new psychology based on purely physiological experimental methods.

N. N. Strakhov, an anti-Darwinist and one of the pillars of metaphysics, sharply criticised *Psychological Studies* in a review in the reactionary magazine *Grazhdanin* (*Citizen*). Opposing Sechenov on all of his principal points, Strakhov formulated his own view thus: "The point is that of the *duality* of our world, of a *cardinal difference* between physical and psychical phenomena."

Strakhov did not confine himself to criticising Sechenov's book; he returned to the attack in a special work of his own *Fundamental Concepts of Psychology*, published in 1878. It was diametrically opposed to Sechenov's book. This was understandable, since Strakhov, being an idealist and anti-Darwinist, proceeded from the principles which were the reverse of those advocated by Sechenov. For Strakhov man was the centre of the world, whereas for Sechenov man was a link in the development of nature. According to Strakhov, the "spirit" exists independently of the body—the two elements being subordinated to different laws; according to Sechenov, unity of "spirit" and body is the principal factor. That which is called spiritual activity was for Sechenov the property of matter at a definite stage of development of organic nature.

Sechenov's struggle for a genuine materialist elaboration of the problems of psychology, so strikingly reflected in his controversy with Kavelin, met with a wide response all over Russia in the seventies and eighties of the last century. This found its reflection in the memoirs, diaries and letters of his contemporaries, and even in the literature of the day. As the famous satirist Saltykov-Shchedrin figuratively expressed it, Sechenov's voice in the controversy was that of a deep bass, Kavelin's that of a gentle tenor.

The question of the importance of human practical activity in the process of knowledge, a question which was alien to idealist psychology, arose before Sechenov, who reconstructed psychology on a materialist basis.

In his article "Impressions and Reality" he referred to the viewpoint which claimed that "we receive via our sense organs only a series of conventional signals from the objects of the external world". In this connection Sechenov posed the following question: "How is it possible to reconcile this apparently conventional cognition of the external world with the achievements of natural science, thanks to which man is acquiring more and more power over the forces of nature? How is it that natural science, which deals only with conventional sensory signals emanating from inaccessible reality, creates an increasingly harmonious system of knowledge, knowledge which is most effective, being constantly justified by its brilliant application—by its success in the sphere of technology?"

Sechenov reached the height of theoretical generalisation in his treatise "The Elements of Thought", which contains an historical analysis of the formation of complex psychical phenomena beginning with the most elementary manifestations of irritability and sensation. He skilfully analysed the laws governing the formation of abstract notions of objects of the external world on the basis of man's perceptions, on the basis of the signalling activity of a number of sense organs; in other words, he was the first in the history of science to advance the idea of the formation of so-called abstract thought in the course of man's development, in the process of his interaction with objects of the external world. In this work he again reverted to the problem—which he had posed previously—of the unity and interaction of organisms and the conditions of existence, the latter being regarded by him as a decisive factor in the evolution of the structure and functioning of the nervous system.

In "The Elements of Thought" he formulated in an absolutely new way a number of important generalisations concerning the role of the so-called "muscular sense" in the physiological analysis of perception of time and space. The writing of "The Elements of Thought" was an extremely arduous task. On February 27, 1878 he wrote to I. Mechnikov: "At last, I have finished 'The Elements of Thought'. This long-drawn-out work called for such a tremendous effort that it is doubtful if I shall ever tackle a job like it again. Personally, I think that it will greatly facilitate the study of logic; if so, I should consider it a great merit from the practical point of view. Besides, it contains some points which have matured deep within me (for instance, the ideas concerning the role of muscular sense in the analysis and measurement of space and time). But people are often poor judges of their own work."*

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* *The Struggle for Science in Tsarist Russia.* A Collection of unpublished letters by I. Sechenov, I. Mechnikov, L. Tsenkovsky, V. Kovalevsky, S. Vinogradsky, M. Kovalevsky and others. P. 96. State Publishing House of Socio-Economic Literature, 1931.

Later he revised and considerably supplemented the work which appeared in book form in 1903.

Sechenov devoted more than thirty years to a profound study of psychical phenomena. K. Timiryazev, in an appraisal of the fundamental achievements of world natural science in the nineteenth century, emphasised the outstanding contribution made by Sechenov. According to Timiryazev, Sechenov was one of the most profound researchers in the sphere of scientific psychology, a researcher "who did not falter at its most complex problems and who undertook their solution with . . . the caution of the scientist and the insight of the thinker. . . ."

In his old age, at the end of the nineteenth century, Sechenov conceived a grandiose plan for further researches which opened up broad vistas for materialist elaboration of psychology. The ideas contained in his lectures, and later in his book *An Essay on the Working Movements of Man*, are of great importance for an exhaustive comprehension of his views on psychology.

To analyse from the physiological aspect the various forms of the influence exerted by man on the objects of the external world and thus draw new conclusions concerning the formation of human thought in the process of labour—such was the task which Sechenov set himself. Unfortunately, this research was interrupted at its very outset. It was Sechenov's swan song.

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With the publication of the second edition of *The Elements of Thought* in 1903, Sechenov no longer reverted to the problems of objective, natural-scientific study of psychical processes so thoroughly analysed by him. In that year at the International Medical Congress in Madrid Ivan Pavlov read his first paper on conditioned reflexes.

Following the trail blazed by Sechenov, Pavlov staunchly and consistently advocated the objective study of the higher nervous activity. Sechenov's ideas, statements, and brilliant conjectures were thoroughly substantiated by Pavlov and corroborated by a multitude of incontestable facts. He not only developed Sechenov's theory, he inaugurated the Pavlovian trend in physiology and medicine, and elaborated classical methods by means of which the objective study of the physiology of the brain could be accomplished.

And so Sechenov's dream, expressed as early as 1863 in his *Reflexes of the Brain*, came true; addressing his readers Sechenov wrote: "In view of this, the reader will agree that the time will come when men will be able to analyse the external manifestations of the functioning of the brain as easily as the physicist analyses now a musical chord or the phenomena of a freely falling body."*

Pavlov repeatedly stressed the significance of Sechenov's work in developing research in the sphere of the physiology of the higher nervous activity. In the introductory chapter of his classical *Twenty Years of Objective Study of the Higher Nervous Activity (Behaviour) of Animals* he wrote tracing the history of the problem under his elaboration: "... the chief impetus to my decision (although I was not conscious of it at the time) came from the brilliant pamphlet by Ivan Mikhailovich Sechenov, the founder of Russian physiology. It was entitled *Reflexes of the Brain* (1863) and influenced me as a youth.... This pamphlet was an attempt, brilliant and truly extraordinary for the time (though, of course, only a theoretical one in the form of a physiological outline) to picture our subjective world in a purely physiological aspect."**

It is not merely the identity of scientific problems tackled which brings Pavlov close to Sechenov, but chiefly the militant spirit of his research in the sphere of the physiology of the higher nervous activity. Like Sechenov, Pavlov used all his knowledge and all the facts obtained in his struggle for a truly scientific solution of the age-old problem concerning the correlation between the physiological and the psychical, against all the idealist distortions in this important branch of science. Like Sechenov, Pavlov foresaw the future of science and was firmly convinced that a solution of this problem based on materialistic monism would be found. Almost a quarter of a century has passed since Pavlov's last paper on achievements in the sphere of the physiology of the higher nervous activity was read at

* See page 4 of the present edition.
** I. P. Pavlov, *Complete Works*, Vol. III, Book 1, p. 14, 1951.

the International Congress of Physiologists in Rome, at which I and other Soviet scientists had the good fortune to be present. I vividly recall the fervour with which Pavlov read his paper that contained a number of profound ideas, basically akin to those to which Sechenov had devoted his thoughts and aspirations. "I am convinced," said Pavlov, "that an important stage in the development of human thought is approaching, a stage when the physiological and the psychological, the objective and the subjective, will really merge, when the painful contradiction between our mind and our body and their contraposition will *actually* be solved and disappear in a natural way."*

Appraising Sechenov's classical work in the field of physiology of the central nervous system Pavlov wrote: "Mere impartiality impels us to acknowledge the fact that it was Ivan Mikhailovich who laid the real foundations of the teaching concerning the mechanism of the central nervous system. . . ."**

One of the most important of Sechenov's achievements in this field was his discovery of the phenomena of central inhibition. His fundamental conclusion was that in the central nervous system there are special apparatuses the stimulation of which leads to suppression of spinal reflexes. Thus, Sechenov's theory of central inhibition came to life, and his concept of inhibition took its place in physiology.

Sechenov not only established the fact that in the brain of the frog there is a special region the stimulation of which evokes a pronounced suppression of spinal reflexes; he also found that a combined stimulation of sensory nerves from various areas can lead to suppression of the reflexes of the spinal cord in a reflex way.

Sechenov's discovery of special inhibitory effects of the central nervous system on the reflex acts accomplished by the lower parts of the nervous system greatly influenced the development of the physiology of the nervous system, an influence that is felt to this day. Basing themselves on Sechenov's works, N. Bubnov, R. Heidenhain and N. Wedensky carried out their

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* I. P. Pavlov, *Selected Works*, p. 256. State Publishing House of Political Literature, 1951.

** I. P. Pavlov, *Complete Works*, Vol. VI, p. 266, 1951.

classical investigations in the eighties of the last century and showed the great importance of the inhibitory effects of the brain in the complex acts of co-ordination of movements.

Sechenov's ideas and his discoveries in the physiology of inhibition of the nervous system became the starting-point for the important generalisations of the Petersburg (Leningrad) school of physiology concerning the nature of the inhibitory process as a form and stage of the process of excitation.

Pavlov highly appraised Sechenov's deductions and data relating to the physiology of central inhibition; he regarded Sechenov's treatise and the facts described therein as the first triumph of Russian physiological thought, as the first independent and original work which directly introduced important new material into physiology.

In the process of the further elaboration of Sechenov's work physiology has been enriched with important generalisations in the sphere of the physiology of the nervous system such as Pavlov's theory of external and internal inhibition in the activity of the cerebral cortex, Wedensky's theory of excitation and inhibition as stages of a single excitatory process, the theory of protective inhibition which is of great scientific and practical significance, etc.

Sechenov's "Electrical and Chemical Stimulation of Sensory Spinal Nerves in the Frog", appeared in 1868. In this work Sechenov for the first time in the history of physiology proved that the nerve centres can "summarise sensory stimulations, which are ineffective when applied singly (induction shocks applied to the sciatic nerve), converting them into an impulse producing locomotion provided the stimulations follow one another at a sufficiently high frequency".*

Naturally, the establishment of this important phenomenon entailed a number of new tasks which had not confronted the physiology of the nervous system prior to Sechenov's discovery of the phenomena of summation. In one of his letters concerning this discovery Sechenov wrote: "I am simply dizzy with the mass of accumulating facts which await solution."

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* I. M. Sechenov, *Selected Works*, p. 161. Published by the All-Union Institute of Experimental Medicine, 1935, Russ. ed.

It was at this time that A.I. Tyshetsky, basing himself on Sechenov's discovery of the ability of the nervous system to summarise subthreshold stimulations, began, on Sechenov's advice, to analyse the problem of electrical excitability of the frog's brain, a problem which had had a long history.

Working in Sechenov's laboratory, Tyshetsky for the first time in the history of physiology proved that the cerebral hemispheres of amphibians are susceptible to stimulation and that electrical stimulation of the cerebral hemispheres evokes a motor reaction provided Sechenov's rule of summation of stimulations is observed.

Sechenov's discovery of summation assumed universal significance when a number of researchers demonstrated the frequency and functional role of these phenomena in the nervous system both of vertebrates and invertebrates.

Appraising Sechenov's discovery Pavlov wrote:

"This discovery of Ivan Mikhailovich is a fact of paramount importance in the theory of the central nervous system. The faculty of the central nervous system slowly to come into motion and as slowly to calm down underlies the entire development of nervous activity as revealed in the psychical manifestations of the human brain."*

In 1881, Sechenov published his classical work on so-called galvanic phenomena in the central nervous system of the frog. Using the relatively simple methods of electro-physiological analysis, Sechenov, with his keen eye of experimenter and theorist, was able to detect the so-called rhythmic bioelectrical phenomena in the central nervous system. The string galvanometer, and subsequently amplifying devices and modern oscillographs, enabled later physiologists to describe bioelectrical phenomena in different parts of the central nervous system with the utmost precision, which at present is not only of theoretical but also of practical, clinical importance.

Sechenov's views on the nature and role of rhythmic bioelectrical phenomena in the central nervous system have acquired a special significance in our days. Proceeding from the theoretical proposition that there is a close interaction between

* I. P. Pavlov, *Complete Works*, Vol. VI, p. 266.

organisms and the environmental conditions, and regarding causality as the guiding principle for any naturalist, Sechenov endeavoured to establish the causes which stimulate and maintain rhythmic bioelectrical phenomena.

His views on the nature of the so-called spontaneous or automatic rhythmic activity are of particular importance in our days since more and more often there appear physiological researches and theoretical generalisations claiming the existence of a specific form of vital activity of organisms, supposedly inborn and independent of any environmental influences and opposed to reflex activity. Many of these researches relate to comparative physiology of the nervous activity, the general conclusion being that at early stages of phylogenetic development this form of non-reflex activity allegedly played an independent role. It is in this branch of physiology that the attacks against the reflex theory of vital activity of animal organisms, i.e., against the materialist physiology of Sechenov and Pavlov, are of a particularly violent nature.

Characteristic of Sechenov as a physiologist and experimenter was his desire to link the results of his investigations on animals with problems relating to the physiology and pathology of the human organism. More than any other researchers, he constantly emphasised that scientific data obtained from experimentation on animals should not be transferred to man uncritically. Experimenting on himself he tried to verify the results which he had obtained on frogs when studying the inhibitory influence of the brain on the reflexes of the spinal cord. It is impossible to read without emotion the letters which he wrote to the famous Russian artist Alexander Ivanov then living in Rome describing his life in Leipzig where after experimentation on animals he tried to study on himself the effects of acute alcoholic intoxication. He described, in particular, the strict diet which he had prescribed for himself with the aim of investigating metabolic changes in the human organism under the influence of large doses of alcohol and unvaried diet.

His desire to bring together physiology and medicine was strikingly revealed in his classical works devoted to the absorption of gases by salt solutions. These researches carried out over a period of more than thirty years not only opened a new chapter in the history of physiological chemistry, but made possible precise analysis of gas metabolism in the human and animal organisms under different conditions. Sechenov used all his theoretical knowledge and all his experimental skill to analyse—at the dawn of modern aeronautics—the effects of altitude on respiration and the reasons why aeronauts die in open balloon-cars.

At the Sixth Congress of Naturalists and Physicians held in 1879 after reading his paper that dealt with respiration in conditions of rarefied air and contained an analysis of the causes which led to the death of French aeronauts in the open car of the balloon "Zenith", he was given an ovation by the audience. Commenting on the scene, the magazine *Vrach* (*Physician*) wrote: "There is no need to add that by their ovation the members of the section expressed their deep respect for the author of the paper, the respect which he has long commanded among Russian physicians as a scientist and public man whose word and deed are never at variance."

During half a century Sechenov successfully combined research with teaching. He lectured at the Military Medical Academy, and later at the Petersburg, Moscow and Novorossiisk (Odessa) universities. In these establishments Sechenov not only conducted his experimental and theoretical investigations, making an invaluable contribution to Russian and world science and culture, he also trained a galaxy of scientists—physiologists and physicians. Among his pupils were: N. Wedensky, B. Verigo, N. Kravkov, V. Pashutin, M. Shaternikov and many other outstanding scientists. His pupils, in turn, taught a new generation of scientists many of whom are now well-known Soviet physiologists.

Throughout his life Sechenov ardently popularised the achievements of science among the public; this, in his opinion, was the sacred duty of the scientist. He devoted the last year of his life exclusively to the noble work of popular enlightenment. In 1903, at the age of 74, now a renowned scientist, the founder of Russian physiology, he lectured on human anatomy and physiology at the Prechistenka classes for workers. In his *Autobiographical Notes* he recalls this period with feelings of great affection for his audience which consisted of Moscow factory workers.

However, the last thing the tsarist government wanted was close contact between a materialistically-minded scientist and an audience of workers. The Director of Elementary Schools refused to confirm Sechenov as a teacher at the Prechistenka classes.

Thanks to the researches of outstanding physiologists in the second half of the nineteenth century, including the highly important contribution of Sechenov and his school, the physiology of the nervous system made such headway that at the beginning of the twentieth century the question of establishing special scientific institutes in a number of countries arose. In 1904 the International Association of Academies was discussing the question of opening special scientific centres for the study of problems relating to the morphology and physiology of the central nervous system. The matter was raised in the Russian Academy by Academician F. Ovsyannikov.

However, in the conditions of tsarist Russia the opening of a centre of this kind was impossible—the state allocations for science were too miserly; besides, it was hopeless to expect an allocation for a scientific centre which would busy itself with problems connected with the materialist analysis of the functioning of the brain, as clearly intimated by the works of Sechenov and Pavlov.

It was only after the Great October Socialist Revolution that all branches of science, including physiology, were given free rein for development. It can be said that special attention was paid to physiology; and this was because physiology in Russia was headed by Pavlov, the continuer of Sechenov's work, whose researches were considered by V.I. Lenin as being "of enormous significance for the working people of the world".

* * *

Sechenov died on November 2 (15), 1905. He caught a chill on a wet and cold autumn day and was laid low with pneumonia. The illness undermined his strength. Three hours before his death he said to the nurse at his bedside: "I know I am dying." Shortly afterwards he lapsed into unconsciousness and never recovered.

His remarkable heart ceased to beat; the brain which had penetrated into the innermost secrets of nature no longer functioned.

Right up to the day of his death Sechenov devoted himself to creative work for the good of the people. "We must work, work and work"—these words were said by Sechenov to Timiryazev at the last meeting of the two great scientists, two weeks before Sechenov's death and on the eve of the great events of 1905. "Those were the last words I heard from him," wrote Timiryazev, "the behest of a mighty generation upon leaving the stage to the generations to come."

K. Koshtoyants

COMPLETE CONTENTS OF THE SOVIET EDITION OF VOLUME I OF SECHENOV'S *SELECTED WORKS*

POSTSCRIPT

During the last week of November 1963 the centenary of the publication of Sechenov's "Reflexes of the Brain" was commemorated in Moscow by a series of three symposia: (1) "Brain Reflexes" and Central Inhibition; (2) General Principles of Self-Regulation in Cortico-Subcortical Correlations, and (3) Evolutionary Physiology of the Nervous System and Brain Ontogenesis. The symposia were sponsored jointly by the Soviet Academy of Sciences and the International Brain Research Organization (IBRO-UNESCO).

The meetings were described in the issue of *Science* of February 7, 1964.* The organizing committee provided the visiting scientists from more than a dozen countries with an informative review of current neurobiological and behavioral research in the Soviet Union. Soviet biophysicists, mathematicians, and engineers concerned with studying the nervous system participated less prominently in these meetings. This may be somewhat surprising in the light of the accusations made at the time of the publication of the book in 1863 (see Note 1, pp. 111–113) and in view of Sechenov's repeated attempts to draw analogies between the functioning of animals and machines. In 1889, considerably in advance of the Zeitgeist, Sechenov's first lecture at Moscow University dealt extensively with the nervous system as a control mechanism:

> These facts can be easily reconciled if we draw a parallel between the muscles and glands with their nervous mechanisms, on the one hand, and machines, on the other. In this case a muscle, abstracted from its nervous connections, can be regarded as an essential component of a machine designed to perform mechanical work, and the nervous apparatus as an accessory device corresponding to the regulators which enable the mechanic to operate his machine, to accelerate, decelerate or stop its work

*D. P. Purpura and H. Waelsch, "Brain Reflexes," *Science,* 1964, *143,* 598–604.

> altogether. The nervous system initiates the work of the muscles and of (certain) glands, and since the functioning of this system, like that of a machine, is at times accelerated (due to certain requirements of the organism), or decelerated and even stopped altogether it is clear that the entire regulation derives from the nervous system.
>
> In most machines the regulation is done by the operator whose hand brings a particular device into action. But there are some regulators which replace the operator's hand: they come into action, so to speak, automatically, but actually under the influence of certain changes in the functioning of the machine. The safety valve of Watt's steam-engine is the best known example of such a regulator. As the pressure of the steam in the boiler exceeds a definite limit, the valve automatically widens the exhaust outlet, and vice versa. The numerous devices of this kind are called automatic regulators.
>
> In the animal, which is a kind of self-acting machine, the regulators are also automatic, being brought into action by the changes in the state of the machine or in its functioning. As the work of these regulators is expedient, they replace the hand of the operator which is guided by his mind.

There is little need to justify the publication of this monograph in English at this time. Sechenov is an important figure in the history of brain science. He had working contacts with Du Bois-Reymond, Helmholtz, Claude Bernard, and other outstanding physiologists of his era. His reflexological approach to the understanding of behavior was a pioneering attempt not only in Russia but throughout the Western World.*

When Professor E. Asratyan (chairman of the organizing committee of the Sechenov Symposium) learned that Sechenov's works are not generally available in English, he offered his help in remedying this situation. He provided us with a copy of the first volume of Sechenov's *Selected Physiological and Psychological Works.*** In welcoming the first publication of "Brain Reflexes" in the United States, Professor Asratyan comments

*See E. G. Boring, *A History of Experimental Psychology* (2nd edition), Appleton-Century-Crofts, Inc.: New York, 1950, for a discussion of Sechenov's importance in the development of behavioristics; see also M. A. B. Brazier, *A History of the Electrical Activity of the Brain,* Macmillan Co.: New York, 1961.

**Published in English by the Foreign Languages Publishing House in Moscow (1952–1956).

on this "classic work . . . of the recognized father of Russian physiology."

> This work marked a real turning point in the science of brain and opened a new era in the history of neurophysiology and psychology. His innovating ideas served as a mighty stimulus for the development of many branches of science on a new basis, and were the prelude to the materialistic teaching of I. P. Pavlov on higher nervous activity. From this point of view Pavlov may be rightfully called Sechenov's disciple. Some of the facts and conceptions presented in "Brain Reflexes" gave a start to a continuously growing number of investigations on the physiology of central inhibition in all the civilized countries of the world, and, to a certain extent, investigations in the field of reticular formation physiology, which is now occupying one of the central places in modern neurophysiology. "Brain Reflexes" is not only a golden page in the history of physiology; up till now it remains an up-to-date instrument for analysis of many complicated phenomena of brain activity, an old, but effective weapon in the scientific polemics on many acute problems of modern neurophysiology.

Permit me who participated in the Sechenov Symposium — during those tragic days of the end of November 1963 — to add a minor footnote. Sechenov wrote his book at the time the Massachusetts Institute of Technology started its institutional existence. However, "Brain Reflexes" relates to M.I.T. more directly than by being a mere contemporary; his author is a too little appreciated intellectual forebear of Norbert Wiener. The author of *Cybernetics, or Control and Communication in the Animal and the Machine* and Sechenov who wrote — almost a hundred years earlier — that " . . . to every naturalist the idea of the machine nature of the brain is a godsend" belong to the same intellectual tradition.

WALTER A. ROSENBLITH

Massachusetts Institute of Technology
December 1964

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