THE FUNCTION OF THE PARTS WITHIN THE STRUCTURE OF THE WHOLE: THE EXCITABILITY OF THE NERVES AS A PHENOMENON OF LIFE[1]

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Excitability is a fundamental property of all animals and men, and of all living parts. The physiologist speaks about the excitability of the nerves and muscles, and its loss is a sign of dying. The physiologist calls excitability (*Erregbarkeit*) also irritability (*Reizbarkeit*), which probably originates from the fact that the formations which he studies are isolated parts of the animal organism which show only reduced characteristics of life. The physiologist makes no distinction between excitability and irritability, although this is given in the original meaning of the words. His object, e.g. a frog nerve, is given to him as a relatively constant object. The nerve is in a condition called excitability or irritability, which, however, shows itself only when a stimulus is applied, known to the researcher merely as a physical process. Then the nerve becomes excited, irritated, changes its condition, i.e., something happens which spreads further from the point of stimulation and has its effect in other areas. Excitability is thus measured by the sensitivity to stimuli. Although this definition uses vital concepts loaded with meaning—to excite, to sense, stimulus—the physiologist is meant to understand them only as expressions which refer to physico-chemical processes. For it has become customary in physiology to seek a physico-chemical explanation, and especially tissues of a simple structure, such as the nerve, seem suited to this kind of explanation. However, this has not yet been accomplished. The deeper the investigations penetrate into the processes, the more complex the model must be which represents the data. Maybe some day it will be possible to give a physico-chemical explanation of the excitability of the nerves. Maybe life has there reached its limits, namely, form without content, framework without action, the function of a structure without the structure of a function.

There is, however, a danger in seeking such an explanation. Physiology is inclined to understand the whole from its parts. Conceptions

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gained from the living organism and its behavior are applied to the parts and, consequently, only metaphorically. Thus these concepts become empty, and if one tries to find the way back to the whole from the analytically obtained data, one has no other choice but to use these empty concepts for the interpretation of animal life. In consequence one becomes blind to that which is essential in the processes of life.

It seems to me, however, that even the reduced life of the isolated nerves corresponds fully to the essential meaning of excitability and irritability, though the structure may be less differentiated, the processes more unequivocal, and the polarities, which show themselves clearly in fully developed life, hidden.

1. Physiology teaches: the nerve *responds* to stimuli of a specific intensity. The stimulus has to pass a certain threshold value. What remains on this side of the threshold does not excite the nerve. When the natural scientist reflects on this fact, he conceives of a model, a structured formation, which shows these phenomena. Such symbolic representation has advantages. We can "read off" characteristics of life from every kind of symbol—a flame, a stream of water, an electrical condenser, a steam engine.

But one must then really "*read* off" these characteristics. The symbol shows us the meaning in pictures, as hieroglyphics do; but only reading which replaces these with conceptualization brings knowledge.

The notion of the threshold is obtained from the nerve, and every living being shows such a threshold for stimuli.

Upon careful investigation one finds that even in the nerve the threshold depends upon the kind of stimulation as well as the condition of the nerve. Recent research shows that even in the application of unstructured stimuli which can be varied quantitatively and thus accurately measured, such as electrical stimuli, the threshold of stimulation is determined by the rate of increase of current. It is clear that when electrical stimuli are applied to a relatively simple object such as the nerve, only a small variability is available. Moreover, the electrical stimulus is not adequate (not natural). But when one studies preparations which in physiology are considered complex, such as a reflex preparation, then one must first clearly understand how this object of research differs from a nerve. The idea that the parts of the central nervous system, e.g. a piece of spinal cord, are in principle exceptions

from all other parts of the organism, as if these were the seat of the "soul" and as if the processes were not vital but psychic, is sheer nonsense.

Already the most elementary consideration shows that this notion is untenable. The nerve is a part of the nervous system, which has, so to speak, one dimension less, and is related to the spinal cord, as a line to a surface, or a surface to a three-dimensional object.

This distinction between nerve and spinal cord becomes clear when we consider the Gestalt of the functions. Then one can understand that the stimulation of the nerve does not show a Gestalt and that its threshold can be comprehended almost quantitatively.

The study of an appropriate spinal animal already teaches better what the essence of the threshold is. We find, when we use adequate (natural) stimuli, that the stimulus must have a specific Gestalt to become effective.

The stimulus-Gestalt is meaningful: it is a threat, a contact, an approach, an adherence, i.e., it is one of the possible modes of relation to the environment which one can expect from this spinal animal, this organ complex under investigation. When the stimulus has passed the threshold, this means that some Gestalt has entered into the life space. Only then is the stimulus present.

2. When a stimulus which has passed the threshold is effective through its Gestalt, then there are no longer stimuli which can be distinguished quantitatively. Where, as in a differentiated structure, more stimulus-Gestalten are possible, a weaker stimulus differs from a stronger one in the same way as the stimulus differs when a child or an adult steps over the threshold. The Gestalt which obtains its stimulus-form only in the life space, i.e., in the being-together of living beings and environmental events, is simply present or not.

This *all-or-none law* is also valid for the nerves. We can properly understand this law of stimulation, which has been demonstrated for the isolated nerve, only when we recognize in the nerve a reduced form of life. Each element which exists by itself (nerve fibre, muscle cell), each organ which lives as a whole (the heart), like each individual animal, is subjected to this all-or-none law. Only when in dying the unit disintegrates, then this law is no longer valid for the structure which is now only an anatomical form.

3. The organism is only stimulated when the Gestalt *appears* to it. This is related to what we call time. The threshold is a limit, but not a

line. And that which is living does not always reach its limits. Properly speaking it never reaches its limits. Therefore something can creep over the threshold. Then it enters slowly, and resides inside without becoming effective as a stimulus. Yet it becomes active. The internal environment changes; some things shift around, but not without counter-tensions. The physiologist knows that all this is true also for the nerve. One can allow an electrical current to creep in very slowly. Then, it does not stimulate even when it is of maximum intensity, but evokes only counter-tensions, polarization and electrotonus.

4. One recognizes the stimulus by the response. This is commonly said, but is not accurate. The stimulus without a response is no stimulus. It is only formed by the response.

The study of behavior, as well as the investigation of the central nervous system, show that the stimulus is determined by the subject as well as the object. Whether something becomes a stimulus depends on the organism, on its excitability. In actual excitation, this becomes manifest as movement. Part of the stimulus-Gestalt is the movement, external or internal, of that which has been stimulated. Though it is true that the stimulus only becomes a stimulus in the response, it is also true that in this process the two become distinct at the same time. It is like a development which is started in the meeting of two parts (egg and sperm) and which leads to a formation of separated parts. What we experience as stimulus and response are Gestalten which are formed in this development. What we call stimulus and response in the nerve, are only the beginning and end of a hidden process which externally resembles the full process of life. It takes a while before the excitation has fully formed the stimulus-Gestalt in the response. When we pay attention only to this response, i.e., until it appears as crisis, we form the concept of latency.

This is valid too for the isolated nerve. A quick change of a current of critical strength evokes an inner movement in the nerve: this is the excitation, and only thereby does the physical phenomenon become a stimulus. We see the separation of stimulus and response clearly developed in the higher animal. They are separated more or less in the excitation which apparently follows the stimulation. Thus the excitation appears as crisis, as change, for stimulation means an intrusion in the stream of life which evokes change and crisis.

After the crisis, after the excitation, comes the solution, the re-

lease. When the excitation has taken its course, the sensitivity for the stimulus concerned disappears for a certain period. This is called the refractory phase, and one distinguishes between absolute and relative refractory phases. In the latter, life is less responsive. The sensitivity returns when the organism has returned to its starting condition.

5. As we have said, it is possible for models to represent symbolically certain characteristics of excitability, excitation, and the result of excitation. Except one characteristic—the most important one: Excitability is not a state, but a function, a process. It is a function rooted in the whole of the organic processes, and is determined by what takes place in the whole animal, as it lives in its environment.

The nervous system is a tissue, a whole made up of threads which cross each other. It is spread out in the animal like a carpet whose surface is a design of colored stripes and figures. That which is the same color responds only to a certain kind of vibration.

But it is a miracle carpet—for it is alive. Its design changes with time, often suddenly, at other times gradually. It changes also when it is touched somewhere. Then, not only the color of this place changes but of entire parts as well, which change into new figures and new coherences. There are parts which are very sensitive and others whose excitation induces far-reaching changes. The carpet runs through many rooms, the happenings in which are reflected again in its design.

The halls are narrow and long. The hall runners do not have a real design but only longitudinal stripes which, however, are colored. They are the so-called nerves, which change their color in relation to the events in the carpet and the rooms.

This has been shown by physiological research. The excitability, when seen in the light of a specific object of research, is a sensitivity to certain vibrations. The parts, cells and fibres, are attuned; they are most sensitive to electrical impulses of a certain duration. Then even the smallest amount of energy is sufficient to evoke an excitation. How an excitation will spread, depends on its coloration, not on the tissue. It spreads through resonance.

Everything that takes place in the animal—posture and movement, hidden vegetative processes as well as outside influences—produces a change in the arrangement of those parts which are attuned in the same way. We said, therefore, that excitability is not a state but a function, a process. In this way the multiformity of behavior is formed. A part of the nervous system is also embedded in the organs as

peripheral tissue. Whatever takes place in these cells, their metabolism, their excretions; the muscle tensions; the stimulation of the sensory cells—all this affects the central part, which changes the design of the great rug which we call spinal cord and brain. When I isolate parts, the variety of the possible reorganizations is lessened; the functions become dedifferentiated.

What can be shown in the nerves by means of well-controlled experiments can be understood from what has been said. One finds that the fibres in the nerve differ according to sensitivity, refractory period and conduction speed. These properties change when the nerve is severed from the central nervous system, when parts of the central nervous system are removed, and when something happens in the so-called sympathetic nervous system. The excitability of the nerve changes through the chemical agents (hormones) of the organs. But it is also determined by the periphery, by the sensory cells, and changes in muscle tonus. And all this remains in equilibrium, in balance, as long as the nerve is still a part of the whole. The unbalanced results are found in experiments and also when the nerve is connected only with the muscle. It is found least in the isolated nerve alone.

Then the color of the stripes no longer changes, they fade out, and finally disappear completely. Then the nerve is constant and corresponds to the ideal of a science oriented towards simple physical models.

The excitability, studied in the nerve of a frog, can be understood only from the image which the life of animals and of man presents to us. The study of parts does not supply ideas and concepts to understand the organism as a whole, but the experience derived from the whole shows the way to understand the functions of even the simplest parts.