WHAT IS A NERVE IMPULSE?

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It is generally supposed that nervous energy is some form of electricity, since a nerve can be activated by an electric charge. But there would seem to be indications that something other than electricity is here involved because, although a nerve impulse may be excited by means of an electrical stimulus, the response of the nerve is independent of the stimulus.

Consider the following facts established by clinical experiment:

1. An electric charge must be of threshold intensity to produce a reaction in a nerve. This intensity differs according to the nature and the condition of the nerve fiber.

2. A stimulus of more than threshold intensity will generate the same response in the nerve regardless of whether it is strong or weak. The response is therefore independent of the electric charge. It is occasioned by it, but not caused by it.

3. The electrical excitation of a nerve is followed immediately by a period of varying length in which the nerve is either absolutely refractory (that is, resists any electrical stimulus), or relatively refractory (that is, requires a stronger stimulus to produce a response).

4. An electrical stimulus produces a response only in a small segment of the nerve. This response acts as a stimulus to the neighboring segment, and this to the next one, etc. The nerve impulse, therefore, is only started by the electric charge, and thereafter proceeds, segment by segment, without it.

5. The rate at which a nerve can be actuated by successive charges of electricity varies ordinarily from 5 to 50 per second. Occasionally the rate may rise to 100 per second. The rate at which a nerve segment recovers from being totally refractory is such in some fibers, however, as to permit a potential of being activated 1000 times per second.

6. The speed of conduction of energy along a nerve fiber varies according to the diameter of the fiber and the thickness of its myelination. Large fibers, more thickly myelinated, conduct more rapidly than small and thinly myelinated fibers.

On the basis of these and other established facts, the transmission of a nerve impulse has been explained in accord with what is called the "core conductor theory, or the membrane hypothesis" as follows:

1. When the nerve is at rest, the nerve cell membrane and that of its axon, the axolemma, are the seat of an electromotive force which gives rise to the resting potential of the cell. Sodium and potassium exchange takes place through the resting membrane. No flow of current occurs because the potential is the same at all places on the resting cell membrane.

2. The application of a threshold stimulus at a point in the nerve fiber causes a break-down in the membrane at that point, and locally abolishes the membrane potential. A potential difference is thus brought about between the normal regions of the nerve and this region of break-down, and in consequence local currents are set up.

3. These currents cause a break-down of membrane potential of the neighboring segment, which causes local currents to be set up there, and the break-down process spreads along the nerve fiber like a flame along a fuse.

4. The break-down is rapidly repaired, and at any time only a small segment is broken down. As an impulse travels along a nerve, the region of break-down is in an absolutely refractory state.

5. During activity in the axon, potassium is lost through the membrane, and sodium is gained.

(Talmage L. Peele, M.D., *The Neuroanatomical Basis for Clinical Neurology,* New York: McGraw-Hill Book Company, Inc., pp. 14–17.)

Commenting on these facts, we would point out that while a nerve impulse can be produced, or at least started by an electrical charge of more than threshold intensity, nerve impulses are normally produced without any electric charge. There is no suggestion of electricity in the impact of a sound wave upon the nerve endings in the ear, nor in the impact of light upon the nerve endings of the retina, nor in the impact of dissolved particles upon the taste buds of the tongue. Yet each of these inaugurates a series of nerve impulses.

There is no clinical proof that an electric charge can produce a sensation either of hearing, of sight, or of taste. Yet these are the end-product of nerve impulses from the surface of the body.

There is no indication that what we call an act of will, which inaugurates a series of nerve impulses along motor nerves and produces muscular activity, is an electric charge. If so, it is a unique kind of electricity, since similar reactions cannot be produced in the laboratory.

What, therefore, we ask, starts the chain of nerve reactions when no electric charge is present?

Why does a segment of a nerve fiber become absolutely, or relatively, refractory immediately following an electric charge? It would seem to be because, while the nerve is active it is impervious to electricity, and this would tend to indicate that nervous energy and electricity are quite different things.

What causes the "break-down" of a "membrane potential" to be "repaired?" How can we account for this without postulating some force other than electricity?

Swedenborg postulates another force, which he calls the "animal spirit." Nothing he says about this nerve force is incompatible with the clinical facts recorded above; but everything he says about it offers a possible, and reasonable, explanation of those phenomena of nervous energy which cannot be accounted for by electricity alone. A study of what is meant by the "animal spirit" in the light of modern scientific knowledge would, we believe, be very enlightening.