THE ORIGIN OF NERVE FORCE

TO any one taking a general view of the present position of physiology, there are few things more striking than the deficiency of our knowledge respecting the source of the current which traverses the nervous system, and is brought into play through the instrumentality of its various parts. That the current itself is electricity in some form or another, is almost universally acknowledged, but in what part of the body it originates, or from what store of energy it is derived, is more than most have attempted to answer. The question is made more difficult than it would otherwise be, from the fact that in all those animals which exhibit external electrical phenomena to any extent, such as the Torpedo and Gymnotus, there are large and elaborate special organs for the development of the shocks they produce, but no similar mechanicism, and nothing approaching to it, can be detected in man or other animals, whereby an electrical current or charge might originate. The brain and the various ganglia are often compared to the batteries of a system of electric telegraph, but how they would act if they were such, it is almost impossible to explain.

Direct evidence, therefore, failing to give a satisfactory solution of the problem as to whence nerve force originates, it is necessary to appeal to the indirect in endeavouring to obtain an answer. The hypothesis of "the survival of the fittest" evidently presupposes that after the struggle for existence has lasted a certain time, the individuals which remain, economise to the utmost all the forces at their disposal, because the more perfect use that a living being can make of the limited forces at its command, the easier will it be for it to continue to live. The Rev. Samuel Haughton from the resulting very strongly marked economy of the animal mechanicism, has deduced the principle termed by him that of "least action in nature." The generalness of this principle makes it necessary, if there is evidence of the existence of any store of energy in the living body apparently unemployed, to endeavour to find whether its effects have not been overlooked, or included with those of some other force; and if, at the same time, a force is at work whose origin is unknown, to try and prove whether the two are in any way related to one another. As shown above, there is a force which is in continuous action, with an unexplained origin; the question then resolves itself into whether there is a source of energy in the living body, whose effects have not been explained, and if so, can it on any known or probable grounds, be considered competent to give rise to the nerve current? An endeavour will now be made to show that both parts of the question may be answered in the affirmative; in other words, that there is an available source of energy, as yet unrecognised, of which the function is therefore not yet explained, and which is quite capable of giving rise to the nerve current.

This physiologically new source of energy is *the differences of temperature between the interior and surface of the living body*. Those who are unacquainted with the principles of the modern doctrines of thermo-dynamics, will readily perceive that a difference of temperature in two bodies is a source of power, when they consider that a low-pressure steam engine depends, for its power of doing work, on the difference of temperature between its boiler and condenser; and that a current may be maintained through a copper wire, if it is connected with a thermo-electric battery of which the two ends are kept at different temperatures. In what are termed hot-blooded animals, that is, in mammals and birds, the difference of temperature between the surface and the interior is considerable under all natural circumstances, and in them there is a regulating action of the skin, by which they maintain a uniform internal temperature, always hotter than the surface, whatever that of the external medium may be. In the sluggish so-called cold-blooded animals, the temperature of the interior of the body is but slightly different from that of the air or water in which they live; that it must be higher is evident from the fact that destruction of tissue is continually going on in their bodies, which is always necessarily attended with the evolution of heat.

Such being the case, it is evident that in the difference of temperature between the surface and the interior of the living body there is an available source of energy, which is almost certainly employed advantageously throughout the whole animal kingdom; and what is more, it may reasonably be supposed to be that which gives rise to the electrical nerve current, as only one assumption is involved, and that not an improbable one, it being that a thermo-electric current is capable of being generated between soft tissues of different composition or structure. Physicists will be able to decide this question experimentally, and if they do so, they will do a service to physiology.

For the distribution of a current so generated, the construction of the nervous system is perfectly suited. Two sets of conductors are necessary, the one to carry the currents from the skin to the central organ, which arranges the direction that they must take, and the other to send them on to their destination; these are to be found in the afferent and efferent nerves. As in the telegraph system, no return conductor is necessary; for as the ends of the wires are put into connection with the earth, by which they are able to communicate, so the terminations of the nerves in the skin, muscle-corpuscles and otherwise where they lose their insulated coverings, place the extremities of the afferent and efferent nerves in communication through the intervention of the mass of body tissue. The brain and minor ganglia would then act like greater and lesser offices for the reception and transmission of currents in the required directions, being in fact the commutators of the system.

There are several of the most important phenomena exhibited by the nervous system which are very satisfactorily explained on the above hypothesis. For instance, in cold weather the impulse to action is much more powerfully felt, than in summer when the air is hot, and therefore the temperature of the surface is higher. It is well known that it is impossible to remain for more than a very short time in a hot water-bath, of which the temperature is as high as, or a little higher than, that of the body, on account of the faintness which is sure to come on, and this may be reasonably supposed to be the result of the cessation of the nerve current, which is consequent on the temperature of the surface of the body becoming the same as that of the interior. This faintness is immediately recovered from by the application of a cold douche. When great muscular exertion has to be sustained, as in running or rowing, it is always necessary to have the clothes very thin, and it is felt during the time that it is necessary for the continuance of the effort, that the surface of the body must be kept cool.

As the termination of the nerves in the skin must correspond, on this hypothesis, with the cooled end of a thermo-electric battery, therefore the brain, which is very abundantly supplied with blood, and is the part of the body to which most of the nerves are directed, must be compared with the heated end; and as it is by the conversion of heat into electric current that the nerve force is developed, it is evident that heat must, to a certain extent, disappear as such in the brain, and that that organ must consequently be colder than the blood which enters it. This is exactly what Dr. John Davy observed in the case of the rabbits he experimented on, and his results have not been shown to be incorrect.

A paper on this subject by the present writer appeared in the June number of the *Journal of Anatomy and Physiology*.

A. H. GARROD