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Spontanean Activity of nervous Cells.

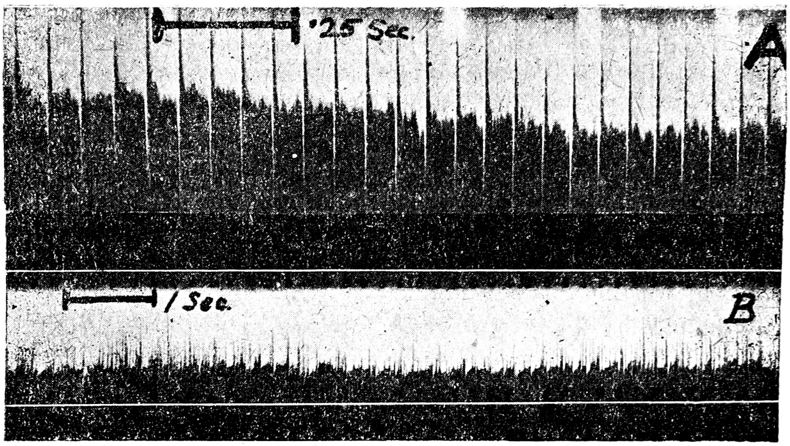
By Prof. **E. D. Adrian.**

The electric changes which occur in living cells have been associated with some of the most distinguished names in physiology and in the last fifteen years we have lost four workers in this field all of whom have made outstanding contributions to their subject. They are, in the order of their loss, Keith Lucas, Garten, Einthoven and now Samojlow. These four may be fitly grouped together because their technique, their published records and their method of attack on their problems shows throughout a quality all too rare in scientific work, a quality which is best described as „elegance". Photographs of the moving lights and shadows which record an action current may be ugly and unsatisfying or they may be well arranged and clear, exact demonstrations of the point which their author wishes to bring out—satisfying both intellectually and aesthetically. No one who studies the records of these men can doubt that they had some of the qualities of the artist as well as those of the scientist and so their work is not only convincing but beautiful as well.

Keith Lucas, the youngest of the four was my teacher in physiology and I can well remember his great appreciation of Samojlow's work; I am deeply honoured at having the opportunity to express in these pages my own appreciation of the worthy man, who was a scientist of such eminence, so cultured and charming a man.

We are accustomed to think of the nervous system as a great controlling station for reflexes. In life it is continually played upon by the streams of afferent impulses which enter it from the sense organs and the movements which it produces are related, directly or indirectly, to these incoming messages. A state in which no sensory messages were allowed to reach the brain and spinal cord would be completely abnormal, yet it is of interest to enquire whether the production of such a state would lead to a complete cessation of all activity in the central nervous system; in other words must all nervous activity be of reflex origin or can it develop in some of the neurones of the brain and cord in the absence of all afferent impulses. There are many indications which point to spontaneous activity in certain regions. Graham Brown has drawn attention to the alternating walking movements which may occur in an animal so deeply anaesthetised that the most intense sensory stimulation produces no reflex response. Here it appears that the motor centres in the cord become active and inactive with a definite rhythm although they are out of the reach of afferent messages. Again the rhythmic movements of breathing are certainly carried out after division of a very large number of the afferent pathways which might play upon the respiratory centre and as every surgeon knows they persist in a stage of anaesthesia which is deep enough to abolish all reaction to painful stimuli. From another point of view it might be said that there is no reason against the occurrence of spontaneous activity in certain neurones. Striated muscle is active only when impulses reach it along the nerves, but other kinds of muscle, cardiac and unstriated become active and inactive without nervous intervention and without obvious change in the external environment.

Although we are ultimately concerned with the vertebrate central nervous system we can learn something about the behaviour of the neurone by studying its reactions in less complex structures. Nerve cells do not vary much in size and therefore the smaller the animal, the smaller will be the number of nerve cells in its central nervous system and the greater chance will there be of finding out what each neurone is doing. Since we can now amplify electric changes to almost any extent by the triode valve, there is no need to use large masses of nerve tissue to give a measurable effect. From this point of view it is as easy to work with the nervous system of an insect as with that of a mammal, and we are limited only by the difficulties of dissection. These are not as formidable as might be imagined, for in the larger insect the central chain of ganglia and some of the peripheral nerves can be removed without injury owing to the tracheal tubes which form a supporting framework to the more delicate nervous tissue.



Nerve impulses from isolated ganglia of insects. Records made with triode valve amplifier and Matthews oscillograph.

A. Spontaneous discharge of impulses from an isolated ganglion of the Gaterpillar. The impulses from a regular series.

B. Periodic discharge from the isolated abdominal ganglia of Dytiscus marginalis. The discharges occur with the rhythm of the respiratory movements. The electrodes are on one of the nerve trunks attached to the ganglia.

Нервные импульсы от изолированных ганглиев насекомых. Запись при помощи усилителя и осциллографа Метьюза.

А. Спонтанный разряд импульсов в изолированном ганглии гусеницы. Отдельные импульсы складываются в правильный ряд.

В. Периодические разряды в изолированном брюшном ганглии D. marginalis. Разряды совершаются в ритме, соответствующем ритму дыхательных движений. Электроды помещались на один из нервных стволов, связанных с ганглием.

An examination of the central nerve cord of any insect removed from the body and suspended on electrodes shows at once the great activity which takes place in the absence of all afferent impulses. Records made e. g. from the isolated nerve cord of the caterpillar or of the cockroach (P. orientalis) show numerous impulses passing down the cord in a regular or irregular sequence. Activity of this kind may continue for as long as 24 hours in the isolated nerve cord. It ceases at once when the ganglia are crushed or treated with a solution of novocain, and it is not due to afferent impulses from the cut ends of sensory nerve fibres, for these can be shown to remain inactive. The activity can be very easily followed by a modification of the method introduced by Wedensky in which electric waves are converted into sound and detected by ear in this case; the changes are magnified by a triode valve amplifier and are led to a loud speaker. We can then hear the impulses in individual nerve fibres and it is often possible to distinguish the entry of a fresh neurone by the appearance of a fresh series of impulses with a characteristic rhythm.

It is of course possible that all this activity is a reaction of the nerve cells to injury, though it persists for so long that the degree of injury cannot be very great to begin with. But there is one type of activity which seems to be clearly related to the normal behaviour of the animal. The water beetle, Dytiscus marginalis, carries out rhythmic breathing movements at a rate varying from 3—15 a second and a preparation of the thoracic and abdominal ganglion chain of Dytiscus often continues to give rhythmic discharges of impulses at the same frequency. In records of these regular made with one of the electrodes on the ganglion, the most prominent feature of the record is the slow deflection of the base line which accompanies each discharge of impulses in the nerve fibres. The impulses themselves appear as sharp diphasic spikes. It is probable that the slow deflection indicates a slow rise and fall of the active state in the nerve cells and dendrites, the nerve discharge changing in frequency as the active state rises and declines. A more detailed account of these changes will appear shortly in the Journal of physiology: for the present it is enough to point out that the neurones concerned with the movements of respiration need no afferent impulses to determine their discharge. They can „beat" as spontaneously as the heart muscle and their activity in an isolated ganglion chain differs very little from that in an intact animal.

Essentially the same result in an vertebrate has been reported by Adrian and Buytendijk, for they found that the isolated brain stem of the gold fish often shows regular potential changes with the characteristic rhythm of the respiratory movements and in other parts of the brain there is an irregular electrical activity. No doubt different neurones like different kinds of muscle vary greatly in stability, some remaining inactive unless excited by afferent messages, some passing through alternate periods of activity and rest like cardiac muscle and some highly sensitive to slight changes in their environment. It has long been held that the cells of the respiratory centre have a tendency to rhythmic activity, and this is confirmed by the present observations. But in insects it seems clear too that other kinds of movement may be carried out by neurones whose activity depends on an inherent tendency of the cells themselves, a tendency which is modified by but is not entirely dependent on afferent stimulation.