

tion) while a rise in barometric pressure is associated with a reduction in the disappearance time. The respiratory rate of the person (even when kept under uniform temperature conditions) is frequently opposite in trend, *i. e.*, the rate increases when the methylene blue disappearance time is diminishing.

We append a graph of an autonomically unstable patient on whom observations were made from a period of October 25th to December 10th. In this graph the upper curve represents the respiratory rate taken in the morning. It will be noted that it ranges from 8 to 16 per minute. The curve immediately below labeled M.B. represents the disappearance time of the injected dye. The two curves at the bottom of the chart are of meteorological observations. The heavier line marked B.P. being the Chicago barographic record and T, the dotted line, the average daily temperature.

The disappearance time of the injected methylene blue forms almost a mirror image of the barograph.

Without entering into a discussion of the underlying mechanisms we wish at this time merely to call attention to the probable usefulness of methylene blue as an indicator of oxygen reduction potential when so injected.

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Measurement of the Action-Potentials in the Peripheral Nerves of Man Without Anesthetic.

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Our method to secure records of nerve currents in man is to insert one or both electrodes directly into a peripheral nerve. Two types of electrodes are used: (1) A fine wire of platinum-iridium is inserted into the ulnar nerve while a second wire is inserted under the skin at the point of the elbow. The second wire is the so-called indifferent electrode. (2) The tip of a hypodermic needle containing 2 very fine and well-insulated wires, the electrodes, is inserted into the ulnar nerve. The needle itself is connected to ground, while the electrodes are connected with the amplifier input. Possible advantages of this type of electrode over the well-known form of Adrian are under investigation. Electrodes described under (2) are particularly suitable for measuring action-potentials from a

limited area of nerve tissue immediately surrounding the electrodes.

Measurements are made with apparatus previously described,¹ including an amplifying equipment and string galvanometer so that if one microvolt at 60 cycles is impressed upon the input terminals of the amplifier a fairly steady deflection of the string of about 2.4 cm. is obtained. At this setting, if a short-circuiting line is placed across the input terminals, the string shows irregular excursions generally not exceeding 0.6 or 0.7 cm.

Whether the electrode or electrodes actually are in the nerve can be determined as follows: (1) As the needle penetrates the nerve, the subject reports a sudden pang in the ulnar portion of the palm and in the ulnar 2 fingers, sometimes including the middle finger. (2) Leads from the electrodes are disconnected from the amplifier and connected into a circuit containing a dry cell and a rheostat, so that a slight stimulating current can be sent through the tissues between the points of the electrodes. That the electrode or electrodes lie in the nerve tissue is shown by the stimulation causing sudden abduction of the hand ulnarwards. If the wire or needle presumed to be in the nerve is withdrawn so that it penetrates the skin and underlying tissues only several millimeters deep, or if it is pushed in completely but not in the same direction as originally (*e. g.*, hypodermically) stimulation with the slight current fails to cause motor effects characteristic of ulnar motor fiber action; considerable increase of such current likewise fails. (3) With the electrodes in the nerve and connected in the amplifying circuit, the subject upon signal makes slight movements with muscles whose motor supply is solely from the ulnar nerve; for instance, he flexes ever so slightly the terminal phalanges of the ulnar 2 fingers. Thereupon the string movements show the presence of marked action-potentials. A control test is made upon flexing the terminal phalanx of the thumb, when no such action-potentials appear.

The subject, with electrodes suitably attached, lies on a couch with eyes closed, and is requested to relax fully. During a test period, action-potentials are recorded with the photographic paper moving at the rate of one inch per second or at a higher speed. To avoid securing too long a photograph in experiments which last half an hour or more, the camera motor is turned on and off at 3 regular intervals per minute by a clockwork operating a relay switch. Control records are taken upon short-circuiting the input leads of the amplifier, thus eliminating the subject from the circuit. Calibrating

¹ Jacobson, E., *Am. J. Physiol.*, 1930, **91**, 567; 1931, **97**, 200.

records are made, for example, by impressing one microvolt at 60 cycles directly upon the input terminals of the amplifier and, again, in series with the subject, so that the impressed microvoltage passes through the electrodes and the tissues between them.

Measurements can thus be made from photographs of the nerve action-potentials of an individual, normal or diseased. The results can be stated as the total microvoltage for the entire period, as the average microvoltage per second, or as the average peak microvoltage per second. The changes in microvoltage in the electrodes during the period can be represented in a graph. Possible clinical applications will be apparent.

Following the period of quiet, various stimuli are applied such as might excite the subject; or he engages in some exciting activity while action-potentials are measured. Stimuli include sudden noises, disagreeable sounds, the application of heat and exposure of bright light upon the closed eyelids.

Subjects who have had prolonged training to relax, so far as tested up to date, generally show a line of potential near zero when relaxed. These findings accord with those secured with a larger group of trained individuals in whom measurements have been made with the electrodes inserted in muscle. As an illustration, when one such subject spoke or counted out loud, no marked deviation from zero was noted in action-potentials recorded from the ulnar nerve. But when requested to relate about his father's recent death, a great increase in action-potentials occurred. Upon ceasing his account, following the instruction to relax, the action-potentials decrease in gradual linear manner. After almost zero potential has been regained for several minutes, the same requests are followed by repetition of similar phenomena.